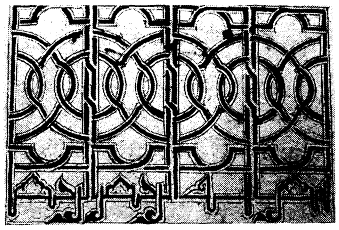
*Encyclopedia of*
*the History of Arabic Science*

# *Encyclopedia of the History of Arabic Science*

Volume 3

*Edited by*
ROSHDI RASHED
*in collaboration with*
RÉGIS MORELON



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# Contents

**VOLUME 1**


Contents v

Preface ix

1 General survey of Arabic astronomy *Régis Morelon* 1

2 Eastern Arabic astronomy between the eighth and the eleventh centuries *Régis Morelon* 20

3 Arabic planetary theories after the eleventh century AD *George Saliba* 58

4 Astronomy and Islamic society: Qibla, gnomonics and timekeeping *David A. King* 128

5 Mathematical geography *Edward S. Kennedy* 185

6 Arabic nautical science *Henri Grosset-Grange (in collaboration with Henri Rouquette)* 202

7 The development of Arabic science in Andalusia *Juan Vernet and Julio Samsó* 243

8 The heritage of Arabic science in Hebrew *Bernard R. Goldstein* 276

9 The influence of Arabic astronomy in the medieval West *Henri Hugonnard-Roche* 284

Bibliography 306

## VOLUME 2


10 Numeration and arithmetic *Ahmad S. Saidan* 331

11 Algebra *Roshdi Rashed* 349

12 Combinatorial analysis, numerical analysis, Diophantine analysis and number theory *Roshdi Rashed* 376

13 Infinitesimal determinations, quadrature of lunules and isoperimetric problems *Roshdi Rashed* 418

14 Geometry *Boris A. Rosenfeld and Adolf P. Youschkevitch* 447

15 Trigonometry *Marie-Thérèse Debarnot* 495

16 The influence of Arabic mathematics in the medieval West *André Allard* 539

17 Musical science *Jean-Claude Chabrier* 581

18 Statics *Mariam Rozhanskaya (in collaboration with I. S. Levinova)* 614

19 Geometrical optics *Roshdi Rashed* 643

20 The emergence of physiological optics *Gül A. Russell* 672

21 The Western reception of Arabic optics *David C. Lindberg* 716

Bibliography 730


## VOLUME 3


22 Engineering *Donald R. Hill* 751

23 Geography *André Miquel* 796

24 Botany and agriculture *Toufic Fahd* 813

25 Arabic alchemy *Georges C. Anawati* 853

26 The reception of Arabic alchemy in the West *Robert Halleux* 886

27 Medicine *Emilie Savage-Smith* 903

28 The influence of Arabic medicine in the medieval West
*Danielle Jacquart* 963

29 The scientific institutions in the medieval Near East
*Françoise Micheau* 985

30 Classifications of the sciences *Jean Jolivet* 1008

Postface: approaches to the history of Arabic science
*Muhsin Mahdi* 1026

Bibliography 1045

Index 1067

# 22

# *Engineering*

DONALD R. HILL

## INTRODUCTION

The history of engineering in Islam is a very wide subject indeed, and it is not easy to do it justice in a single chapter. The intention is to present the reader with a fair and accurate picture of the scope and significance of Muslim achievements in this field, and to indicate how Muslim engineers served the needs of society and how, in a number of instances, their work was of importance in the development of modern engineering. To realize this intention in the space available some omissions are inevitable. In the first place, and without entering into a lengthy discussion about the precise meaning of the term, 'engineering' is taken here as a concept that involves some degree of complexity. In civil engineering, small structures such as dwelling houses and short-span bridges have in general been disregarded. In the mechanical field devices that require the frequent and repeated use of the human hand have been omitted. There is therefore no direct discussion of hand tools, personal weapons or textile machinery. An exception is made in the case of instruments – surveying and astronomical – because of the mathematical skills required for their construction and use. It may well be argued that these omissions, and others, are of immense importance to human society. So they are, but they are not – except in the widest possible sense – engineering.

In many cases the places and dates of origin of machines or techniques have not been established with any certainty. It is not proposed to devote much space to an examination of the evidence for the origin of any particular invention, particularly if it is known that it occurred before the advent of Islam in the first/seventh century. The estimated time and location of origin will be given, with an indication of the conjectural element in this estimate and the possible alternatives, if any. It should be noted that many pre-Islamic inventions were made in the Middle East when the area was under Greek or Roman hegemony. While the inclusion of the area in wider cultural spheres undoubtedly provided a favourable environment for innovation and the diffusion of new ideas, it is nevertheless the case that a number of inventions came from among the indigenous peoples of the area.

Medieval Islam was a prosperous and dynamic civilization, and much of its prosperity was due to an engineering technology that assisted in increasing the production of raw materials and finished products. In addition, the demand for scientific instruments, and the need to cater for the amusements and aesthetic pleasures of the leisured classes, was reflected in a tradition of fine technology based upon delicate mechanisms and sensitive control mechanisms. In this paper, the contribution of engineering to Islamic civilization will usually be demonstrated by specific examples, since space does not allow for a detailed survey of the interactions between technology and society. Similarly, the Islamic contribution to the development of modern engineering will be indicated by means of citing individual cases of technology transfer.

## CIVIL ENGINEERING

### Irrigation and water supply

For the sake of convenience it is necessary to divide the subject of civil engineering in the Muslim world into several sections, but in fact much of the subject is broadly contained within the field of irrigation and water supply. Dams are used to impound and divert irrigation water, bridges to cross canals and surveying techniques to align and level canals and *qanāts*. Water-raising machines, which are discussed under mechanical engineering, are of course an integral part of hydraulic engineering schemes. In this section, therefore, we shall confine our attention to the principal irrigation systems, and to the means for transporting water to the fields and to urban communities.

There are four different types of irrigation. *Basin* irrigation, which was the method used in Egypt from ancient times until quite recently, consists of levelling large plots of land adjacent to a river or a canal, each plot being surrounded by dykes. When the water in the river reaches a certain level the dykes are breached, allowing the water to inundate the plots. It remains there until the fertile sediment settles, whereupon the surplus is drained back into the watercourse. *Perennial* irrigation is a method of watering crops regularly throughout the growing season by leading the water into small channels which form a matrix over the field. Water from the main artery – a river, major canal or *qanāt* – is diverted into supply canals, then into smaller irrigation canals, and so on to the fields. *Terrace* irrigation is a method used in hilly country and consists of the formation of a series of terraces stepped down a hillside. Irrigation is by means of stored rainfall, wells, springs and occasionally *qanāts*. *Wadi* irrigation depends upon sporadic rainstorms in otherwise arid lands. It consists of impounding the storm water behind dams and using this water to irrigate the fields adjacent to the watercourses. The famous dam at Ma'rib in the Yemen was the focal point of such a system. Following its original construction in the eighth century BC it was successively raised, not to impound water for long periods but to raise the wadi floods to increasingly higher levels in order to irrigate more and more land by means of a canal system which used the wadi itself as a drain. The final breakdown of the dam is thought to have occurred about a quarter-century before Muḥammad's birth. From the second century BC until the beginning of the first century AD the Nabateans in southern Palestine and Jordan developed a thriving agriculture based upon wadi irrigation. Whereas irrigation in the Yemen depended upon a single large dam, the Nabateans built thousands of little barriers sited across one wadi after another in order to divert or capture the one or two weeks of runoff occurring each year.

All these methods of irrigation originated in Antiquity and it cannot be said that any radically new techniques have been added to the repertoire of Egyptian and Mesopotamian engineers. It could scarcely be otherwise: the basic problem of impounding the water, conducting it to the fields and finally draining the surplus remains as it has always been. Irrigation, and particularly perennial irrigation, however, is a branch of civil engineering which has always demanded a high degree of technical and administrative skills. The construction of dams, canals and *qanāts*, matters to do with water flow and control, and elaborate surveying problems, all present themselves uncompromisingly and demand the attention of experts. From one area to another, there will always be differences in hydraulic conditions, climate, soil and terrain, so that the engineers must apply their knowledge and experience to produce the best system for a given set of conditions.

It is sometimes said that large cities are one of the main characteristics of Islamic civilization, and it is of course true that great cities such as Baghdad, Cairo and Cordoba, with their flourishing economic, commercial and intellectual life, were a major component of that civilization. It hardly needs emphasizing, however, that life in these large urban centres would have been impossible without the support of a thriving agriculture. Many Muslim cities were founded after the advent of Islam – e.g. Baghdad, Basra and Shiraz – and we therefore find that the efforts of the engineers were taxed to the utmost either in extending existing systems or in creating completely new ones. When the Abbasids assumed power in the second/eighth century the existing Sasanid irrigation system in central Iraq was greatly expanded, mainly to cater for the needs of the new city of

Baghdad, whose population at its zenith was about 1 500 000. The network of canals between the Euphrates and the Tigris was extended, the great Nahrawan canal to the east of the Tigris was lengthened and two new systems on the rivers Uzaym and Diyala were added. Earlier, the city of Basra had grown from a simple military encampment to a great urban centre during the course of the first/seventh century. A completely new irrigation system, taking its waters from the Shatt al-Arab was constructed and extended to keep pace with the growth of the city. Even in the first half of the fourth/tenth century, when Basra was in relative decline, the geographer al-Iṣṭakhrī was astonished to see the enormous network of canals around the city.

Although there was some irrigation in Spain in Roman and Visigothic times, the large systems along the River Quadalquivir and in the province of Valencia were Muslim achievements. The rulers of al-Andalus and many of their followers were of Syrian origin, and the climate, terrain and hydraulic conditions in parts of southern Spain resemble those of Syria. It is hardly surprising, therefore, that the irrigation methods – technical and administrative – in Valencia, for example, closely resemble the methods applied in the Ghuta of Damascus. There were many other irrigation systems in the Muslim world, ranging from the great canal networks of Egypt and Iraq, down to village fields watered from one or two wells. One of the largest systems was centred on the city of Marw in Khurasan on the River Murghab, which provided the irrigation water for extensive farmlands. In the fourth/tenth century the superintendent of irrigation at Marw was said to have had more power than the prefect of the city, and to have supervised a workforce of 10 000 men. Greatly surpassing this, however, was the province of Sughd – now part of the Uzbek Republic. The mainstay of its fertility was the Sughd river, now called the Zarafshan, which flowed through the great cities of Samarkand and Bukhara. At the height of its prosperity in the third/ninth and fourth/tenth centuries the province was rich and fertile beyond compare, its agriculture supported by a vast network of canals extending for many miles around the two cities.

Given the large numbers of men required to construct, maintain and control the large irrigation systems, it is hardly surprising that most of the enterprises were under State control, although it was not unusual for work to be let out to subcontractors. There are one or two Arabic treatises which tell us a good deal about the methods used for surveying and excavating new canals and for maintaining existing ones. We shall discuss land surveying in a separate section, but a section on quantity surveying in a treatise written in Iraq in the fifth/eleventh century is worth mentioning, since it also provides us with information about irrigation works in general. Instructions are given for calculating the quantities of earth to be excavated from canals of given lengths, widths and depths and for converting these quantities into manpower requirements. The canal banks were reinforced with bundles of reeds, and the man-hours required for preparing and placing the bundles are given. For excavation, the number of diggers (celled 'spades') was first calculated, and to these were added the numbers of carriers to each spade, which depended on the distance the spoil had to be carried. Overheads for ancillary workers and supervision were then added. There was a set price for each task, so in the end a Bill of Quantities was produced which would provide the estimate for the cost of the works and serve as a guide for the recruitment of labour. Or, if the project was let out to subcontract, the Bill of Quantities would be the main document for awarding the contract and for the subsequent measurements and payments. Quantity surveying methods have not therefore changed materially over the centuries. From this treatise, and elsewhere, we get a picture of a highly organized State enterprise, with an army of bureaucrats, engineers and surveyors, controlling a very large labour force, whose productivity and rates of pay were closely specified.

It is not usually easy to separate irrigation from water supply because both systems were derived from the same hydraulic works. Thus a dam would provide for both the town supply and the needs of the farmers, with one main feeder channel going to the irrigation system and another into the town. Or a canal would be led out from the main feeder canal into the urban centre. It was collected in a reservoir inside, or just outside, the city walls, and was conducted from there through pipes or open channels to the baths, fountains, houses for ritual ablutions, private and public buildings, and gardens. A particularly impressive example of artificial storage reservoirs can still be seen just outside the city of Qayrawan. Two large linked cisterns for receiving the waters of the Wadi Merj al-Lil when it was in flood were completed in the year 248/862–3. Although they appear to be circular, both are actually polygonal, the larger having a diameter of just under 130 m, the smaller one a diameter of 37.4 m. The smaller receives the waters of the wadi and acts as a settling tank; a circular duct several metres above its base connects it to the larger cistern, which has a depth of about 8 m. On leaving the larger cistern, the water is decanted a second time into two oblong covered cisterns.

One of the most effective methods for providing water in regions without perennial streams is the *qanāt*, an almost horizontal underground conduit that conducts water from an aquifer to the place where it is needed. The technique probably originated in Armenia or northern Iran in the eighth century BC and later spread to many parts of the Middle East. It was in widespread use in the Muslim world in the medieval period and up to modern times. Indeed, recent estimates have shown that 75 per cent of all water used in Iran at the present time comes from *qanāts* and that their total length exceeds 100 000 miles. The city of Teheran alone has thirty-six *qanāts*, all originating in the foothills of the Elburz 8 to 16 miles away, with a measured flow of 6.6 million gallons a day in spring and never below 3.3 million in the autumn. Outside Iran *qanāts* are still in use in parts of the Arab world, notably in the south-east of the Arabian peninsula and in North Africa.

The construction of *qanāts* is in the hands of experts (*muqannī*) and the secrets of the profession are largely handed down by word of mouth from father to son. The termination of the *qanāt*, either farmland to be irrigated or a community to be provided with potable water, or both, will be known in advance, as will the general location of likely aquifers. One of the main skills of the *muqannī* lies in determining, by examining the alluvial fans for traces of seepage and hardly noticeable changes in vegetation, precisely where the trial well is to be dug. When the excavators reach the impermeable layer the well is left for a few days while the *muqannī* estimates the potential yield of the well by hoisting up measured quantities of water and at the same time observing any fall in the water level. If necessary, further wells are sunk to ensure that genuine groundwater has been reached; the shaft with the highest yield is chosen as the 'mother well'. The next step is for the surveyor – or senior *muqannī* – to determine the route, gradient and precise outlet of the *qanāt*. The route will be selected according to considerations of terrain and, in some cases, questions of ownership. To start the survey, a long rope is let down into the mother well until it touches the surface of the water, and a mark is made on it at ground level. The surveyor then selects a spot on the route 30 to 50 yards from the mother well for the first ventilation shaft. A staff is held on this spot by a labourer, and the surveyor measures the fall with a level. Nowadays a modern surveying level may be used but in earlier times one of the instruments described in the section below on surveying was used. A second mark is made on the rope coinciding with the measurement on the staff; the distance from this mark to the lower end of the rope will be the depth of the first ventilation shaft. He continues to level in this way along the route, marking the rope at the location of each shaft, until he reaches the end of the rope. He has then reached a point on the ground at the same level as the surface of the water in the mother well. For the mouth of the *qanāt* he now chooses a place below this level, but higher than the fields, and divides the drop from the level point to the mouth by the number of proposed ventilation shafts and adds this amount to the previously surveyed depth of each shaft. In this way he determines the gradient of the conduit, which is usually from 1 : 1000 to 1 : 500.

After completion of the survey, a number of guide shafts, about 300 yards apart, are driven under the supervision of the surveyor. Then the rope with the marked length of each vertical shaft is handed to the *muqannī*, who now begins to work with his assistants by driving the conduit into the alluvial fan, starting at the mouth. At first the conduit is an open channel, but it soon becomes a tunnel. Another team sinks ventilation shafts ahead of the tunnellers, and labourers haul the soil up to the surface through these shafts. Two oil lamps are kept burning on the floor of the conduit; sighting along these, the *muqannī* keeps the tunnel in alignment, and they also serve as a warning of poor air, since they go out before there is a danger of a man suffocating. As the work nears the mother well great care has to be taken in case the *muqannī* misjudges the distance and strikes the full well, in which event he might be swept away by the sudden flow. It can be seen, therefore, that the construction of *qanāts* is a special example of the difficult and dangerous profession of mining (see Figure 22.1). It may be considered as one of the most successful of man's inventions, since it has been in continuous use for over 2500 years.

## Dams

Dams are required in most hydraulic systems, whatever their purpose, but the functions of dams vary. In wadi irrigation, as we have seen, they are used to trap the floodwaters that result from heavy but infrequent downpours, so that the water-level is raised above that of the surrounding fields, to which it can then be conducted under gravity. For perennial irrigation dams are used to divert water from streams or rivers into the canal network. The impounding of rivers behind dams gives more control over the supply

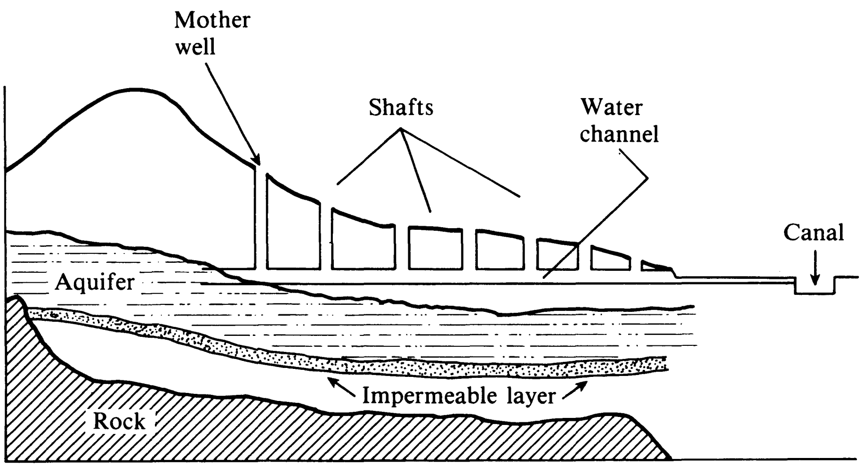



*Figure 22.1*

throughout the year. As with wadi irrigation, it also allows the water in the reservoir to be gravity-fed into irrigation and town supply systems. A further advantage, if the water is to be used for hydro-power, is that there is a high, fairly constant head of water, which would not be the case if the river were unregulated.

There are two basic types of dam – gravity and arch. The first, as its name implies, relies upon the weight of the dam to withstand the pressure of the water. For additional strength, buttresses are sometimes added to the downstream wall. As with all hydraulic structures, good foundations are of the utmost importance, since failure can occur if the scouring action of the water undermines the foundations. Arch dams are designed to resist the force of the water and silt by horizontal arch action and are adaptable only to those sites where the length is small in comparison to the height and the sides of the valley are composed of good rock to resist the arch thrust at the haunches. With very rare exceptions true arch dams were not built before modern times.

The selection of the materials of construction was influenced partly by the design of the dam and partly by availability. Earth dams were common and are still in widespread use today. They are perfectly satisfactory for certain kinds of service, provided they have a core of clay or other impermeable material and plenty of overflow capacity, but they are not really suitable for high dams. In certain areas, notably lower Iraq, earth dams were almost universal; they were (and are) quite adequate for diverting rivers into canal systems and, in any case, the cost of transporting large quantities of stone would have been prohibitive. In other areas, where higher dams were needed, some form of masonry construction was necessary. This could be of dressed stone, mortared or not, random rubble or concrete. Quite frequently, dams were constructed by building two masonry walls with a gap between them, and then filling the gap with cheaper material such as earth or rubble. If the dam was designed to discharge overflow water from its crest, this had to be of stone or concrete, since earth would quickly have been worn away by the action of the water.

The Romans were great civil engineers and built many dams in all the provinces of the Empire. There was also a marked increase in dam-building activity in Iran after the Sasanids assumed power in AD 226. It is likely that Sasanid skills in the construction of dams was partly due to Roman influence. In AD 259 the Roman Emperor Valerian with an army of 70 000 men was taken prisoner by the Persian Army under Shāpūr I. The Roman prisoners, among whom were a number of engineers, were set to work to dam the River Karun. The resulting structure, which still exists, is 1700 feet long and has a rubble masonry core set in hydraulic mortar, and the facing is of large cut masonry blocks held in place with both mortar and iron clamps set in lead. Other dams were built later in Sasanid times, notably the great dam at Ahwaz which was over 3000 feet long and about 25 feet thick. The Romans themselves built dams in Syria, North Africa, Spain and Italy.

There was no decline in the tradition of dam building in Muslim times. Indeed, so great were the demands for irrigation water and power that in the more populous provinces dams became more numerous than they had been in pre-Islamic times. Roman and Sasanid dams were carefully maintained, a fact that is proved by the existence in working order of a number of these early dams, e.g. at Homs in Syria and at Merida in Spain. Many new dams were necessary as part of the extensions to the hydraulic systems in Iraq. Some of these were simple earth dams built to divert river water into canals, but others were major civil engineering undertakings. Perhaps the most impressive of these, the remains of which can still be seen, was a diversion dam over the River Uzaym at the point where it leaves the hills called the Jabal Hamrin. The main body of the dam is a masonry wall 575 feet long which at the western end turns through a right angle and continues for 180 feet to form one bank of the canal called Nahr Batt. The dam has a maximum height of something over 50 feet, but this rapidly reduces towards the sides. In fact for the first 150 feet at the eastern end, the dam is only 13 feet high. The cross-section of its central portion has a neat trapezoidal profile, 10 feet thick at the crest and 50 feet thick at the base. The water face is vertical and the air face is built to a uniform slope with the masonry stepped. The dam was built of cut masonry blocks throughout, connected with lead dowels poured into grooves. This is quite a common Muslim technique and in the Uzaym dam was apparently used as a complete alternative to mortared joints. The alignment of the structure is not straight, and this reflects an attempt, as usual, to utilize the natural shape of the site as advantageously as possible.

In Iran the Muslims added dams to the existing Sasanid systems. A new dam called the Pul-i Bulaiti was built at Shustar on the River Karun, the main purpose of which was to provide power for milling. The mills were installed in tunnels cut through the rock at each side of the channel, with the dam providing the necessary head of water. Another example is the bridge-dam at Dizful which was used to power a great water-wheel working a mechanism which raised water 50 cubits and supplied all the houses of the town. The Buwayhids held the real power in Iraq and Iran from 320/932 until 454/1062, and the greatest builder of the dynasty was ʿAḍud al-Dawla. Among his works was the impressive dam called the Band-i Amir, built about 349/960 over the River Kurr in the province of Fars between Shiraz and Istakhr. This dam was seen by the geographer al-Muqaddasī shortly after it was constructed. He speaks of it as follows:

> ʿAḍud al-Dawla closed the river between Shiraz and Istakhr by a great wall, strengthened with lead. And the water behind it rose and formed a lake. Upon it on the two sides were ten water-wheels, like those we mentioned in Khuzistan, and below each wheel was a mill, and it is today one of the wonders of Fars. Then he built a city. The water flowed through channels and irrigated 300 villages.

The dam, which still survives, is built of solid masonry, set in mortar and reinforced with lead dowels. It is some 30 feet high and 250 feet long.

There are many Muslim dams in Spain, a large number of which were built during the fourth/tenth century, the golden age of Umayyad power in the peninsula. In this period, for example, many small dams, or *azuds*, were built on the 150-mile-long River Turia, which flows into the Mediterranean at Valencia. (In passing it is important to note the Spanish word *azud*, from Arabic *sudd*, one of very many modern irrigation terms taken directly from Arabic and certain proof of Muslim influence on Spanish technology.) Eight of these dams are spread over six miles of river in Valencia, and serve the local irrigation system. Some of the canals carry water much further, particularly to the Valencian rice fields. These, of course, were established by the Muslims, and continue to be one of the most important rice-producing centres in Europe. All eight dams are similar in construction, being fairly low with vertical water faces and stepped air faces. The cores consist of rubble masonry and mortar, and the structures are faced with large masonry blocks with mortared joints. Sluices in the outflow canals permitted surplus water to drain back into the river during normal operation, and occasionally they would be opened to their full extent in order to desilt the approaches to the canal mouth. Such scouring sluices are absolutely essential to prevent the silt which collects behind a dam from choking the canal intakes and the canals themselves (see Figure 22.2). The foundations of these dams are massive; the masonry of the structure extends some 15 feet into the river bed and is supported on rows of wooden piles. These relatively massive foundations for low dams are accounted for by the fact that there are occasional dangerous floods in which the flow of the Turia is increased a hundredfold. The dams are then submerged to a depth of nearly 20 feet and must resist the battering of water, stones, rocks and trees. Because they are so low and flat and are provided with deep and very firm foundations, the Turia dams have been able to survive these conditions for 1000 years.

Not the least of the problems facing the builders of dams is that the energy of the water spilling over the crest of a dam can, over the years, undermine the foundations on the downstream side. A satisfactory solution

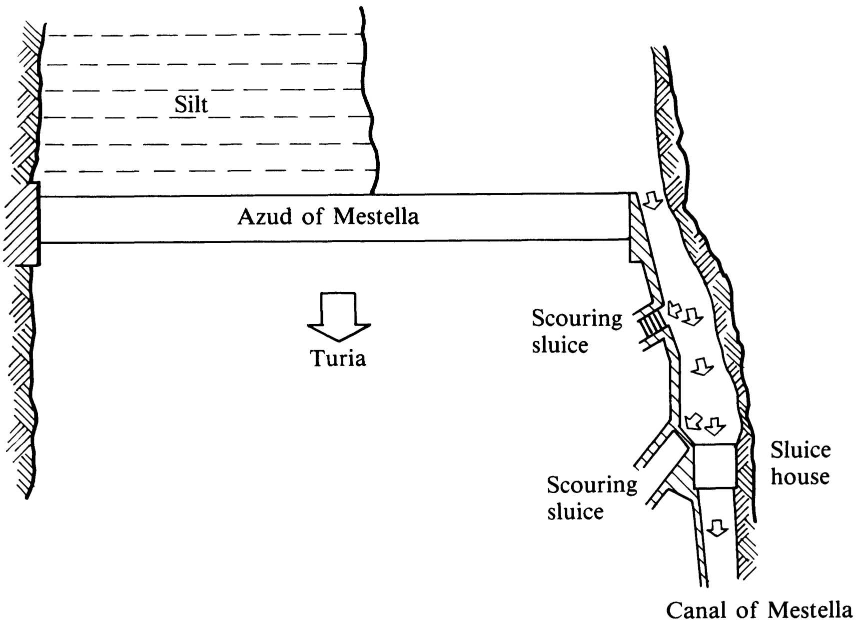



*Figure 22.2*

to this problem is demonstrated by a Muslim dam near Murcia on the River Segura. The air face of the dam had a large surface area, and this was put to good use. Water flowing over the crest initially fell vertically through a height of 13–17 feet on to a level platform, 26 feet wide, running the length of the dam. This served to dissipate the energy of the water spilling over the crest. The overflow then ran to the foot of the dam over flat or gently sloping sections of the face. In this way the whole dam acted as a spillway and the energy gained by the water in falling 25 feet was thereby dissipated, so greatly reducing the risk of undermining the downstream foundations. From this example – and many others could be cited – it is evident that the Muslims had a good empirical understanding of hydraulics.

## Bridges

Suspension bridges with cables made of woven bamboo strips were used in China no later than the first century BC and their use was widespread in China, Tibet, Afghanistan, Kashmir, Nepal, India, Assam, Burma and Thailand. Indeed, communications between peoples in many parts of those countries would have been almost impossible without the suspension bridge. There is no record, however, of the use of a suspension bridge in western Islam or Europe before the Renaissance. This does not mean that they were not used and indeed it would be strange if this simple and effective method of crossing ravines was unknown in the Zagros, the Taurus and the mountainous regions of Spain and North Africa. Similarly, we have no firm evidence for the use of cantilever bridges in Islam, apart from Afghanistan, where they had been built from, at the latest, the fifth century AD onwards. These are also an excellent method of crossing ravines in hilly country, but being made of timber they do not have a long life nor do they leave traces, particularly since in many cases modern bridges may have been built at their sites. Usually a timber substructure is built into a masonry abutment on either bank, and the longitudinal and transverse beams to carry the roadway extend from the top of this supporting structure. At the centre the two cantilever spans support a short beam section (see Figure 22.3). Large modern steel bridges, such as the Forth railway bridge in Scotland, are built on exactly the same principle. In the fourth/tenth century a bridge over the River Tab in Iran was described briefly by Ibn Ḥawqal. He says that the river was crossed by a wooden bridge 'suspended between the sky and the water, its height above the water about 10 cubits'. He may, of course, have seen a suspension bridge, but the cantilever type seems more likely, especially since he makes no mention of ropes.

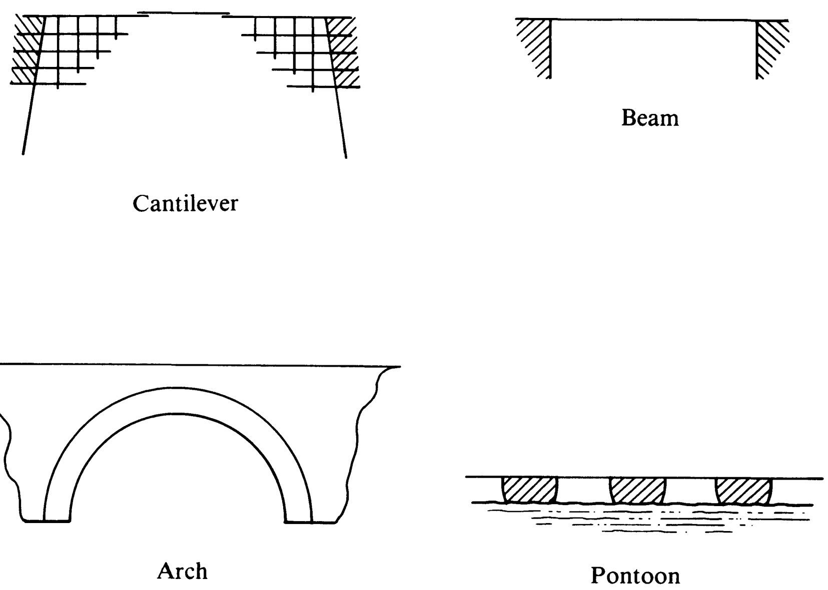



*Figure 22.3*

There are frequent references to pontoon bridges in the works of Arabic writers. They were very common in Iraq for crossing the two rivers and the major irrigation canals. It is worth mentioning that, to the irrigators, the main purpose of any kind of bridge was to prevent people and animals from damaging the banks of canals when fording; the convenience of travellers was a secondary consideration. In the fourth/tenth century there were two pontoon bridges over the Tigris at Baghdad, but only one was in use; the other, having fallen into disrepair, was closed, because few people used it. Ibn Jubayr, writing towards the close of the sixth/twelfth century, described a bridge of large boats over the Euphrates at Hilla. It had chains on either side 'like twisted rods' which were secured to wooden anchorages on the banks. He also mentions a similar, but larger, bridge over a canal near Baghdad. There were also pontoon bridges on the rivers of Khuzistan, the Iranian province adjoining Iraq, and on the Helmand river in Sijistan (now western Afghanistan). There seems to have been a pontoon bridge at Fusṭāṭ (now Old Cairo) in Egypt for many years. In the early part of the fourth/tenth century, al-Iṣṭakhrī says that one bridge crossed from the city to the island and a second bridge from the island to the far bank of the river. About two centuries later, al-Idrīsī describes the same arrangement, adding that there were thirty boats in the first bridge and sixty in the second.

Before the introduction of modern materials the masonry arch provided the best solution for the spanning of watercourses and other obstacles. Although they are relatively expensive to build, well-constructed arch bridges can last for centuries and they do not interfere with river traffic to the same extent as pontoon bridges or the many piers of multiple-span beam bridges. Their durability is proved by the survival of many medieval bridges, intended only for the passage of people and animals, but now sustaining the full load of modern traffic.

Many Roman, Hellenistic and Sasanid arch bridges remained in use in the Muslim world, and the more impressive of these are described in the writings of the Arabic geographers. The Muslims, following the traditions of their predecessors, also built many fine arch bridges. In areas where good building stone was not available, notably in parts of Iran, the bridges were built from burnt bricks, but most of them were constructed from cut stone. The geographer al-Qazwīnī (d. 682/1283) has left us a graphic description of a great arch bridge at the town of Idhaj in Khuzistan; it spanned a ravine that was normally dry, but in times of flood became a turbulent lake. It was built by the Wazīr of the Buwayhid Amīr al-Ḥasan (d. 366/977) who conscripted craftsmen from Idhaj and Isfahan. The bridge was 150 cubits in height and consisted of a single arch, strengthened with lead dowels and iron clamps. The slag from iron workings was used to fill the space between the arch and the roadway. Another remarkable bridge, over the River Tab in Iran, was seen by al-Iṣṭakhrī in the early part of the fourth/tenth century. He says that it was built by an Iranian, physician to the Umayyad governor al-Ḥajjāj (d. 95/714). It was a single arch of span about eighty paces and so high that a man on a camel with a long standard in his raised hand could pass beneath it. A bridge with an unusual purpose was among the works of Ibn Ṭūlūn, governor of Egypt from 254/868 to 270/884. A high causeway 6 miles was constructed from the Nile at Fusṭāṭ towards the west and the bridge, consisting of forty great arches, was an extension to the causeway. The purpose of these works was to provide a passage for the army over the Nile floods if an enemy approached from the west. There were many arch bridges over canals in all the Muslim provinces where irrigation was practised.

## Building construction

Many fine buildings were constructed in the first Islamic century: the Dome of the Rock in Jerusalem, the Great Mosque in Damascus, the second Great Mosques in Kufa and Basra and the desert palaces of the Umayyads – to name only some of the more notable buildings. Once established, the tradition for fine architecture continued to flourish in Islam, as witnessed, for example, by al-Manṣūr's Baghdad, the works of Ibn Ṭūlūn in Egypt, the Great Mosque of Cordoba and the Alhambra palace in Granada, the complex of splendid buildings in Isfahan and so on. Many well-illustrated books have been devoted to describing Islamic buildings and it is clearly beyond the scope of this chapter to attempt even a brief summary of the Muslim architectural achievement. Instead, we shall confine our attention to the most basic element in any building – the materials of construction.

The Muslim geographers usually tell us which type of material was used to construct a given town or city. This could be unfired bricks (*labin* or *ṭub*), fired bricks (*ājurr*), stone (*ḥajar*) or timber. In medieval times timber was more plentiful than it is today, but even so the practice of constructing the main structures of buildings in this material was not widespread. The city of Bukhara was mostly timber-built and the houses in the town of Siraf on the Gulf were made of teak, and timber was also widely used in parts of Spain. Perhaps the most important example of timber used as a structural material is the Dome of the Rock in Jerusalem, in which the dome itself consists of two independent wooden shells, the outer one covered with lead sheets. In general, however, timber was used in conjunction with other materials where some resistance to tensile stresses was necessary, as in lintels over doors and windows, and roof rafters.

The choice of material to be used in a particular building depends upon a number of factors: the availability of a material locally, cost, time and the purpose of the building. Thus it is noticeable that cut masonry was often preferred for religious buildings whereas other large buildings in the same region might be constructed from cheaper materials. Syria can be said to be the region, *par excellence*, for fine stonework in ashlar masonry, i.e. masonry in which each block is carefully cut to size, with straight edges and plane surfaces. This tradition has persisted in Syria to the present day; the local limestone weathers to a beautiful amber colour that is very pleasing to the eye. Ashlar work was also common in Spain (doubtless due to Syrian influence), Egypt and parts of North Africa. Sometimes money and time were saved by building the wall in random rubble and facing it with ashlar. The mortar was based upon either lime or gypsum mixed with soft sand.

The use of unfired bricks was common in early Antiquity and is still widespread today. The clay which is the main constituent of the bricks is readily available in many parts of the world and houses made from this material are warm in winter and cool in summer. Moreover, its use is not confined to the building of small dwelling houses. Some of the multi-storey houses in southern Arabia are made of unfired bricks, and they can also be used in vaults and domes. They cannot, however, be used in areas with high rainfall, for heavy rains cause severe deterioration to the walls to the point of making them disintegrate. The *labina* generally has a geometric, fairly regular shape, that of a parallel-sided rectangle, whose variable dimensions often have the ratio $4 \times 2 \times 1$ (e.g. length 56 cm, width 28, thickness 14, or $36 \times 18 \times 9$) but in South Arabia $45 \times 35 \times 5$ is usual and in Iran $20 \times 20 \times 4$. To prepare the mixture for the bricks, the loam or clay is thoroughly soaked, mixed with straw and chaff and trodden with the bare feet. It is then carried in baskets to the moulders. Each moulder has a wooden mould, just an open frame. He covers the ground with a thin layer of chaff, puts the moulding frame flat on the ground, throws a quantity of the mud-straw mix into the mould, beats it into the corners with his bare hands, and scrapes off any surplus with a small straight-edge. He lifts the frame with a swift movement, leaving the fresh brick on the ground, and places the frame next to the brick just made. Moulding row after row in this way, he makes about 250 bricks in an hour. Unfired bricks are pointed with a mortar made with an a mixture of lime or ash and are usually lined with a coating of earth mixed with lime or plaster.

Burnt bricks were already made in the fourth millenium BC in Babylonia and in Iran kilns have been unearthed going back into the first millenium BC. They are still in common use in many parts of the Muslim world. They are generally smaller than unfired bricks, and the preparation of the clay for them is more thorough – it has to be slaked and sieved to clean it of impurities, and additives are sometimes included, e.g. grey sand to give the bricks a whitish tinge. After moulding they are left in the open, lying flat, for

24 hours, and then turned on edge and left to dry for another three days before being stacked in the kiln. The kiln is similar to that of the potters, and consists of a furnace with a firing room on top of it. Buildings made exclusively from burnt bricks are rare. More usually they are combined with other materials. The Qasr al-Hayr al-Gharbi in Syria, for example, built in the first Islamic century, consists of a wall of limestone, fired bricks and unfired bricks at the top. Burnt bricks were (and are) used for certain parts of buildings such as arches, vaults and staircases, and put to good use by architects to vary the decoration of their works. From the sixth/twelfth century, the glazed brick has offered the possibility of obtaining similar effects to those of mosaic.

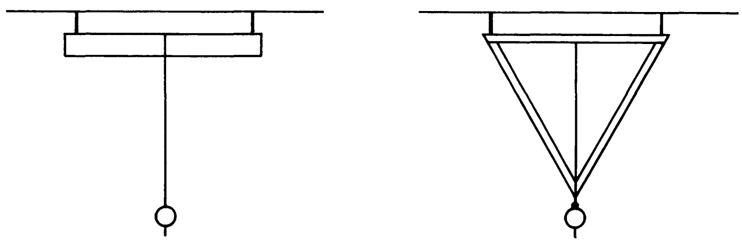
The technique of cobwork (*tabya*) was described in detail by Ibn Khaldūn in his *Muqaddima*, which implies that he thought it a characteristically Muslim practice. Earth with which chalk and crushed baked earth or broken stones are often mixed is rammed between two boards kept parallel by beams. The wall is plastered over, often in such a way as to simulate joints of heavy bond-work beneath. When this plaster falls, the regularly spaced holes left by the beams become visible. In the Muslim West cobwork became general in the fifth/eleventh and sixth/twelfth centuries, especially in military building. In the Maghrib it seems to have been an importation from Andalusia, where it had long been known.

In urban communities, quality control of building was exercised by an official called the *muḥtasib*. His duties were very wide-ranging, since he was appointed by the ruler to supervise the affairs of the market, including the maintenance of moral standards and religious observance; quality and quantity control over retailers and manufacturers; sanitation and water supply; and checking the manufacture of building materials. In this last respect the *ḥisba* manuals (books written for the guidance of the *muḥtasib*) contain a good deal of useful information. For example, the widths of walls and the dimensions of beams were checked with wooden templates, to ensure that the measurements were not less than the minimum specified.

## Surveying

The basic requirements for public works surveying, as in the setting-out of large buildings, the excavation of canals, etc. are levelling and alignment. Whereas nowadays levelling is done with an optical instrument and a graduated staff, in earlier times two such staffs were needed in conjunction with a simple but effective instrument. Three such instruments are described in an Irāqī treatise of the fifth/eleventh century. The first of these is a wooden board about 70 cm long by 8 cm wide. In the centre of the board a line is drawn which meets both edges at a right angle. A plumb line is fixed to this line, near one of the edges. Two hooks are fixed to this edge (see Figure 22.4(a)). The second instrument consists of an equilateral triangle, with two hooks soldered to the ends of one of its sides. A narrow hole is drilled through the centre of this side, to take the cord of a plumb line (Figure 22.4(b)). To use either instrument, it was suspended to a wire or cord stretched tightly between the two graduated staffs. One end of the wire was moved up and down until the plumb line coincided with the line on the board or the corner of the triangle. The difference between the readings on the two staffs gave the level difference. The third instrument is called the 'reed-level'. A narrow longitudinal hole is bored through a long straight reed, and a radial hole is made into this bore at the centre. The reed was held roughly horizontally by two assistants between the two staffs, which were held vertically by two other assistants. A fifth assistant then allowed water to drip into the central hole from a piece of rag. When the flow of water from each end of the reed was equal the reed was truly horizontal. As with the first two instruments, the surveyor then read and recorded the heights on the two staffs. Quite accurate levelling could be carried out over long distances by repeating the operation with any of these instruments. At the end of the survey the 'rises' and 'falls' were totalled and the difference between the totals gave the difference in level between the start and finish points.

For setting out straight lines and for measuring distances ropes were used, with knots at intervals to mark the dimensions. A rotatable alidade, provided with sighting holes and mounted on a plane surface, could also be used for alignment. The astrolabe, which we shall meet in a later section as an instrument for astronomical observation and computation, was also widely used for land surveying. Here we are concerned only with the back of the instrument, which consisted of an alidade turning about a central pivot, its ends moving over a graduated circle, each quadrant of which was divided into 90 degrees. In the lower half of the face was a rectangle, one



(a) (b)

*Figure 22.4*

side of which was divided radially into decimals, the other side into duodecimals (see Figure 22.5 – the other markings on the back of the astrolabe are not relevant to this discussion).

The instrument was used for alignment and measuring the angles between two points, but a number of Arabic writers also describe the solution of various triangulation problems using the astrolabe. The two matching squares into which the rectangle is divided are used for this purpose. Although the squares are divided into ten and twelve equal parts respectively, the choice of number is purely a matter of convenience. With the astrolabe freely

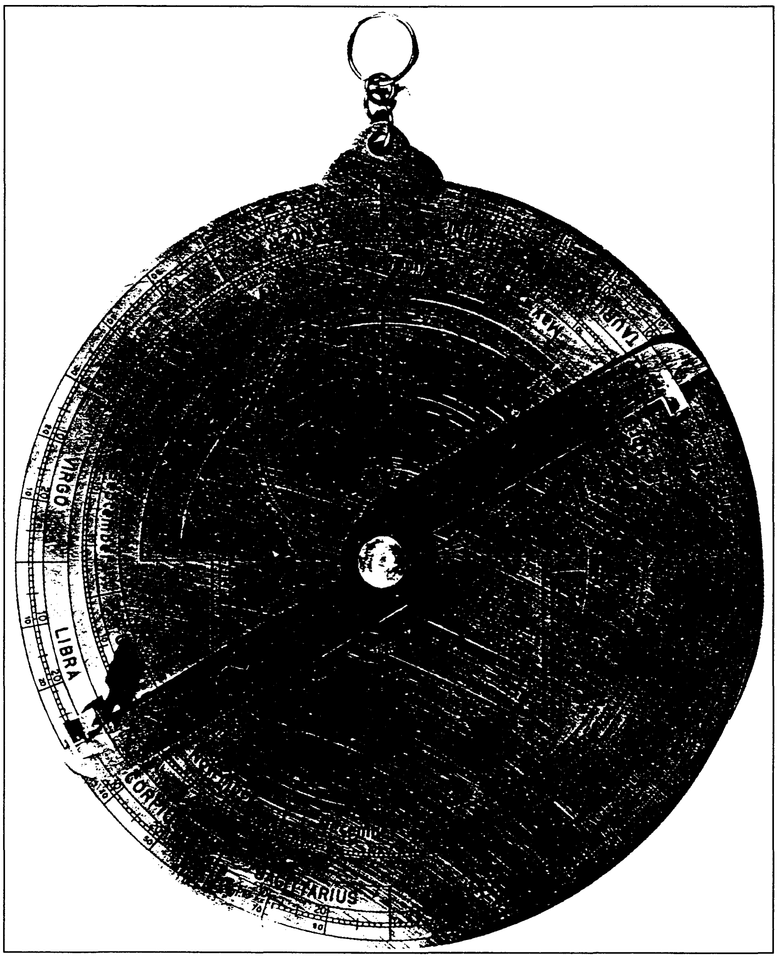



*Figure 22.5*

suspended the alidade is adjusted so that a distant object is viewed through the sights simultaneously. When this happens the real right-angled triangle formed by the distance of the object and its height is reproduced on a small scale within the confines of one square on the astrolabe, by an exactly similar right-angled triangle. The real and similar triangles have a common line for hypotenuse. The ratio of the lengths of the sides of the triangle on the astrolabe is the same as the ratio of the height and distance of the object, so that if either of these is known the other may readily be calculated. If neither is known, the observer reads the angle from one station, moves back a measured distance, and again reads the angle. Since the Muslims had perfected the methods of both plane and spherical trigonometry, problems of this sort could easily be solved. For the surveyor in the field, however, it was clearly preferable to use the constructive methods provided by the astrolabe, and manuals for his use were prepared by scientists. Other problems solved by the use of the astrolabe included finding the width of a river, or the distance between two points separated by an impassable obstruction. Methods of triangulation were unknown to the Roman and were introduced to Spain, for example, by astrolabic treatises written by Muslim scientists.

## MECHANICAL ENGINEERING

### Water-raising machines

The earliest machine used by man for irrigation and water supply is the *shadūf*. It is illustrated as early as 2500 BC in Akkadian reliefs and about 2000 BC in Egypt. It has remained in use until the present day and its application is world-wide, so that it is one of the most successful machines ever invented. Its success is probably due to its simplicity, since it can easily be constructed by the village carpenter using local materials. For fairly low lifts it delivers substantial quantities of water. It consists of a long wooden pole suspended at a fulcrum to a wooden beam supported by columns of wood, stone or brick. At the end of the short arm of the lever is a counterweight made of stone or, in alluvial areas where stone is not available, of clay. The bucket is suspended to the other end by a rope (see Figure 22.6). The operator lowers the bucket into the water and allows it to fill. It is then raised by the action or the counterweight and its contents are discharged into an irrigation ditch or a head tank.

The tympanum or drum was probably invented in Egypt in the first half of the third century BC. Two large timber discs were fixed to a wooden axle which had iron pegs protruding from its ends. The pegs were housed in iron bearings supported on two columns. The space between the discs was

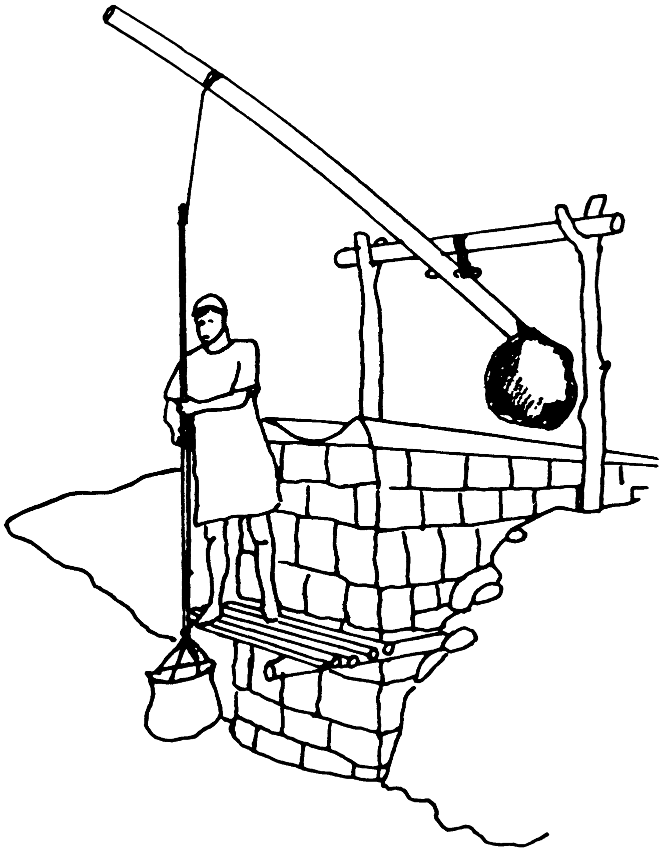


*Figure 22.6*

divided into eight segments by wooden boards. The perimeter was closed by wooden boards, there being a slot in each segment to receive the water. Circular holes were cut around the axle in one face of the drum, one hole to each segment. The whole machine was coated with tar (see Figure 22.7). As the drum was rotated by a tread-wheel, the water was scooped from the source, entered the compartments when they were at the bottom of their travel and was discharged from them when they approached the top. The water ran into a channel and then into a head tank. The drum is rarely mentioned by Muslim writers in connection with irrigation, and its main use seems to have been in de-watering mines. It is ideally suited for this purpose since it can be operated in a fairly restricted space. It was necessary to use a series of drums: the first raised the water into a tank on a platform, a

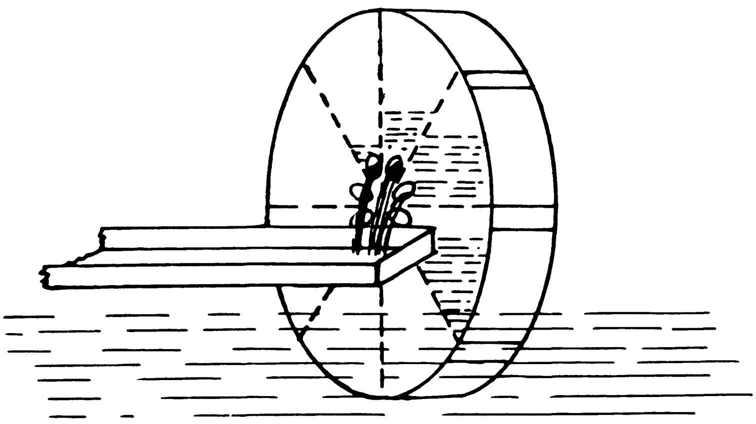


*Figure 22.7*

second drum raised it from this tank to a second tank and so on, until the water was discharged into a drain at the head of the mine.

The screw or water-snail was probably invented by the great scientist Archimedes (*c.* 287–212 BC) when he was living in Egypt and it is therefore appropriate that the machine is often called the 'Archimedean screw'. A wooden blade is fitted spirally to a long cylindrical wooden rotor. A wooden case is made to fit around the blade, constructed like a barrel, the planks painted with pitch and bound with iron hoops. The rotor is supplied with iron spigots which rotate in iron journals. The screw is set at an angle with one of its ends in the water and as it is rotated the water flows along the helix and discharges from the other end. The smaller the angle to the horizontal, the greater will be the rate of discharge. We do not know precisely how the machine was turned in earlier times – it may have been by a tread-wheel, the power transmitted through a pair of gears. Nowadays it is usually operated by a crank, but the crank is not known to have been in use before the sixth/twelfth century. The screw was in common use throughout the Muslim world until quite recently, but now seems to be becoming rarer (see Figure 22.8).

The word *sāqiya* is used here to denote the chain-of-pots driven through a pair of gear-wheels by one or two animals harnessed to a draw-bar and walking around a circular track. This very important machine was invented in Egypt, probably about 200 BC, but did not come into widespread use until the fourth or fifth century AD, with the introduction of the pawl mechanism and earthenware pots. Although it is fairly easy to explain the operation of the machine, it should be emphasized that its construction is quite complex, consisting as it does of over 200 separate components. Only

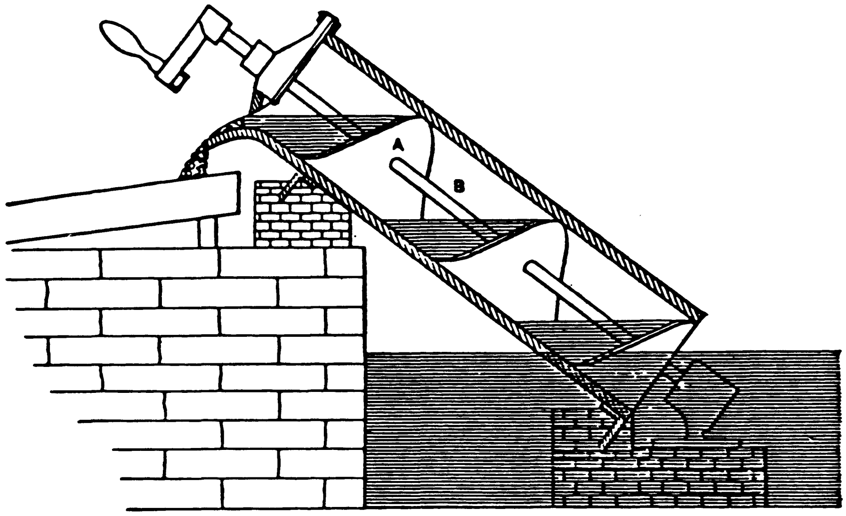



*Figure 22.8*

the basic constructional details will be given here. The draw-bar to which the animal is harnessed passes through a hole in an upright shaft to which the horizontal gear-wheel is fixed by spokes. The shaft rotates in a thrust bearing at ground level and another bearing above the gear-wheel located in a cross-beam which is supported on plinths. The gear-wheel is a lantern-pinion, i.e. two large wooden discs held apart by equally spaced pegs. The vertical gear-wheel carries the chain-of-pots and is often called the pot-garland wheel. It is supported centrally over the well or other source of water on a wooden axle. On one side of it are the pegs that enter the spaces between the pegs of the lantern-pinion and these pegs pass through to the other side of the wheel, where they carry the chain-of-pots. This consists of two continuous loops of rope between which the earthenware pots are attached – sometimes chains and metal containers are used (Figure 22.9).

In order to prevent the wheel from going into reverse, the machine is provided with a pawl mechanism, which acts on the cogs of the potgarland wheel. This mechanism is essential, because the draught animal is subjected to a constant pull both when moving and when standing still. The pawl is activated in two cases – when the animal is to be unharnessed and in the event of the harness or traces breaking. Without the pawl the machine would turn backwards at great speed and, after one revolution, the draw-bar would hit the animal on the head. At the same time, many of the pins of the lantern-pinion would break and the pots smash.

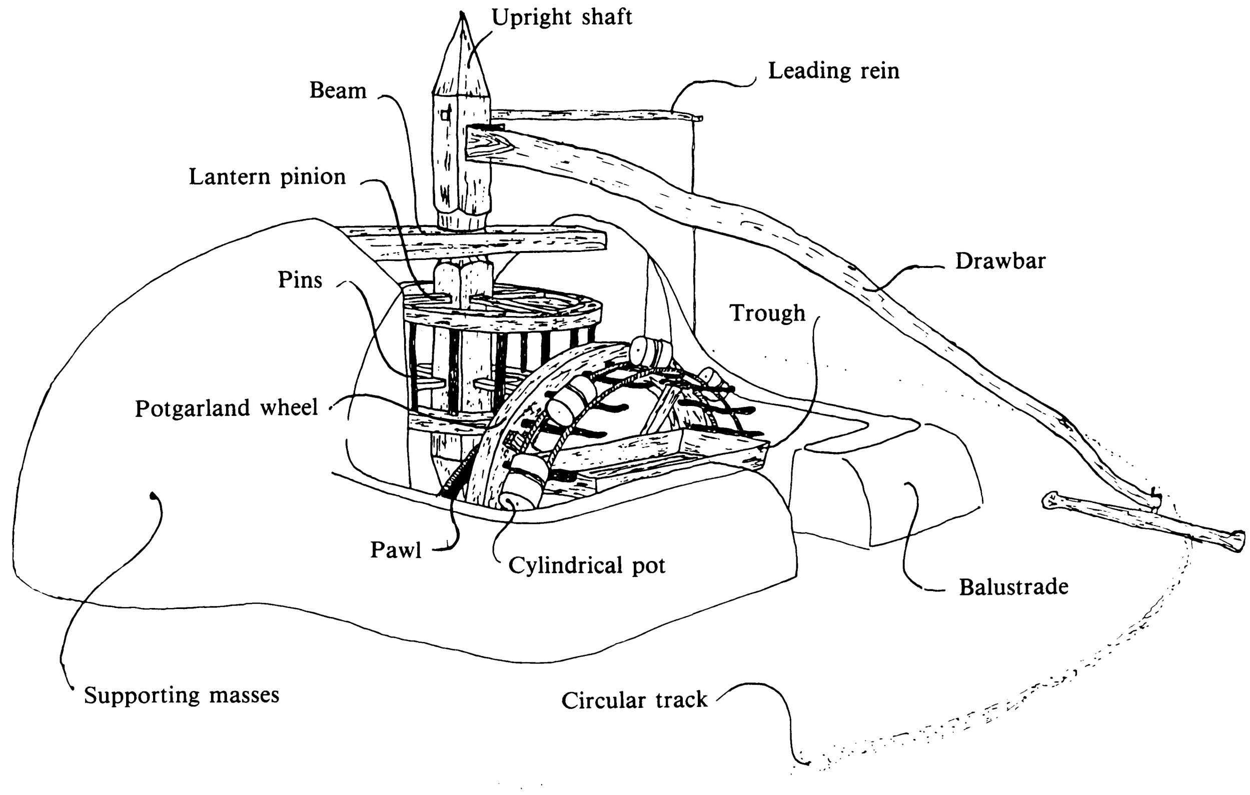

Upright shaft
Leading rein
Beam
Lantern pinion
Drawbar
Pins
Trough
Potgarland wheel
Pawl
Cylindrical pot
Balustrade
Supporting masses
Circular track

*Figure 22.9*

The draught animal may be a donkey, a mule or an ox; sometimes a pair of animals is used. As the animal walks in a circular path, the lantern-pinion is turned and this rotates the potgarland wheel. The pots dip into the water in continuous succession and discharge at the top of the wheel into a channel connected to a head tank. Although the main function of the *sāqiya* is for irrigation it can also be important for water supply when, for example, buildings are some distance above the source of water. The longer the chain-of-pots, i.e. the lift, the lower the rate of discharge will be. For domestic water supply this may not be a crucial factor, but in fact one of the problems of water-raising engineering is that of raising large quantities of water through a small lift. The problem can be solved by using a spiral scoop-wheel (see Figure 22.10), which raises water to ground level with a high degree of efficiency. This machine is very popular in Egypt nowadays, and engineers at a research station near Cairo have been trying to improve the shape of the scoop in order to achieve maximum output. Although it appears very modern in design, this is not the case, since a miniature from Baghdad dated to the sixth/twelfth century shows a spiral scoop-wheel driven by two oxen. The transmission of power is the same as that employed with the standard *sāqiya*.

The *sāqiya* was widely used in the Muslim world from the earliest days onwards. It was introduced to the Iberian peninsula by the Muslims, where it was massively exploited. Not only was it diffused into many parts of Europe but it was also taken to the New World by Christian Spanish engineers. It has advantages over the diesel-driven pump: it can be constructed and maintained by local craftsmen and does not require the importation of fuel. The long history of the *sāqiya* is by no means ended, and there are welcome indications that its advantages will ensure its survival for the foreseeable future.

The *noria* is also a very significant machine in the history of engineering. It consists of a large wheel made of timber and provided with paddles. The rim of the wheel, inside the paddles, is divided into compartments or, in another type of *noria*, earthenware pots similar to those of the *sāqiya*, are lashed to the rim. The wheel is mounted on an axle over a running stream,

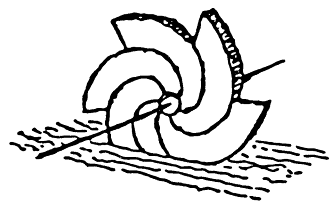


*Figure 22.10*

so positioned that the paddles and the compartments, at the lowest part of their travel, are immersed in the water. The force of the current acting on the paddles causes the wheel to rotate, the compartments fill with water and discharge their contents when they reach the top of the wheel. The water usually collects in a head tank and is then conducted through a feeder channel to the irrigation system or to an urban water supply (see Figure 22.11). Being driven by water, the *noria* is self-acting and requires the presence of neither man nor animal for its operation.

The earliest description we have of the *noria* occurs in the writings of Vitruvius in the first century BC, in words that imply that it had already been in use for some time. It was probably invented around 200 BC in one of the mountainous areas of the Middle East where there are perennial streams – Syria, Mesopotamia or Iran. Its use was widespread in the Muslim world, wherever conditions were appropriate; there are attestations for its use in Iraq, Iran, Mesopotamia, Spain and elsewhere. The most famous *norias* are those at Hama, on the River Orontes in Syria. These are an impressive sight, the largest being over 20 metres in diameter; they discharge into the end of an aqueduct that carries the water to the town and the fields. These machines are known to have been in operation since the third/ninth century, but there were probably *norias* at this site much earlier than this. The large-scale use of *norias* was introduced to Spain by Syrian engineers. An installation similar to that at Hama was in operation at

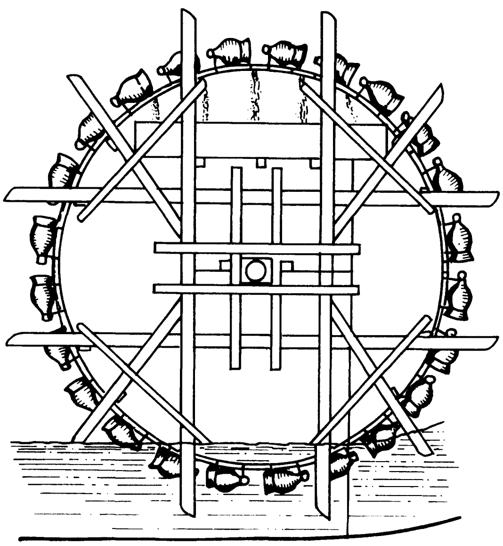
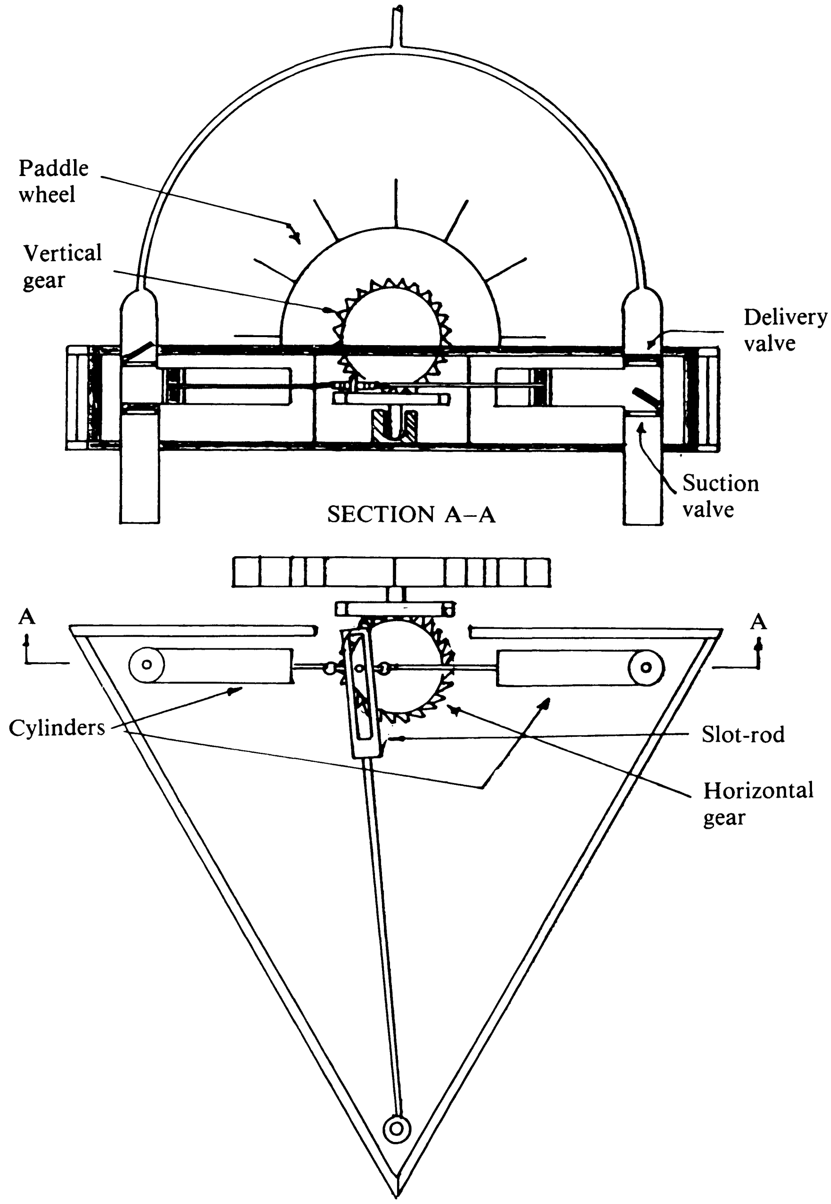


*Figure 22.11*

Toledo in the sixth/twelfth century and the machine was heavily exploited all over Muslim Spain. It was diffused to other parts of Europe and to East Asia, and like the *sāqiya* has shown remarkable powers of survival into modern times.

Five water-raising machines are described in al-Jazarī's great book on machines, composed in Diyar Bakr in 602/1206. One of these is a water-driven *sāqiya*, a type of machine that is known to have been in everyday use in medieval Islam. Three of the others are modifications to the *sāqiya*, obviously intended to raise the output of the traditional machine. These are important for the ideas they embody, ideas which are of importance in the development of mechanical engineering. In one of them, for example, the concept of minimising intermittent working is implied and another incorporates a crank, the first known example of a crank used as an integral part of a machine. The fifth machine is the most significant. This is a water-driven twin-cylinder pump (Figure 22.12). A paddle wheel is mounted on a horizontal axle over a running stream, with a gear-wheel mounted on the other end of the axle. This meshes with a horizontal gear-wheel installed in a large triangular wooden box which is mounted over a pond supplied from the stream. On the face of the second gear-wheel, near the outside, is a peg which enters a slot-rod pivoted at one corner of the box. The connecting rods were fixed to the sides of the slot-rod by staple-and-ring fittings. On the end of each connecting rod was a piston, consisting of two copper discs with a space of about 6 cm between them, the space filled by coiling hempen cord until the gap was filled. The cylinders, made of copper, were provided with suction and delivery pipes, all provided with non-return clack-valves. The two delivery pipes were joined together above the machine to form a single delivery pipe, which discharged the water at a height of about 14 m above the level of the stream. The action was as follows: when the paddle wheel turned it caused the gear-wheel on its axle to turn, and this rotated the gear-wheel in the box and the peg made the slot-rod oscillate from side to side. When one piston was on its delivery stroke the other was on its suction stroke. The important features embodied in this pump are the double-acting principle, the conversion of rotary into reciprocating motion, and the use of true suction pipes. The hand-driven pumps of classical and Hellenistic times had vertical cylinders which stood directly in the water which entered them through plate-valves in the bottoms of the cylinders on the suction strokes. The pumps could not, therefore, be positioned above the water level. A quarter-scale working model of this pump was made for the 1976 World of Islam Festival in the Science Museum, London. The construction is the same as that of the machine described by al-Jazarī, except that the drive was electric. The pump works perfectly, with smooth




PLAN
(lid of box and delivery pipes omitted)
*Figure 22.12*

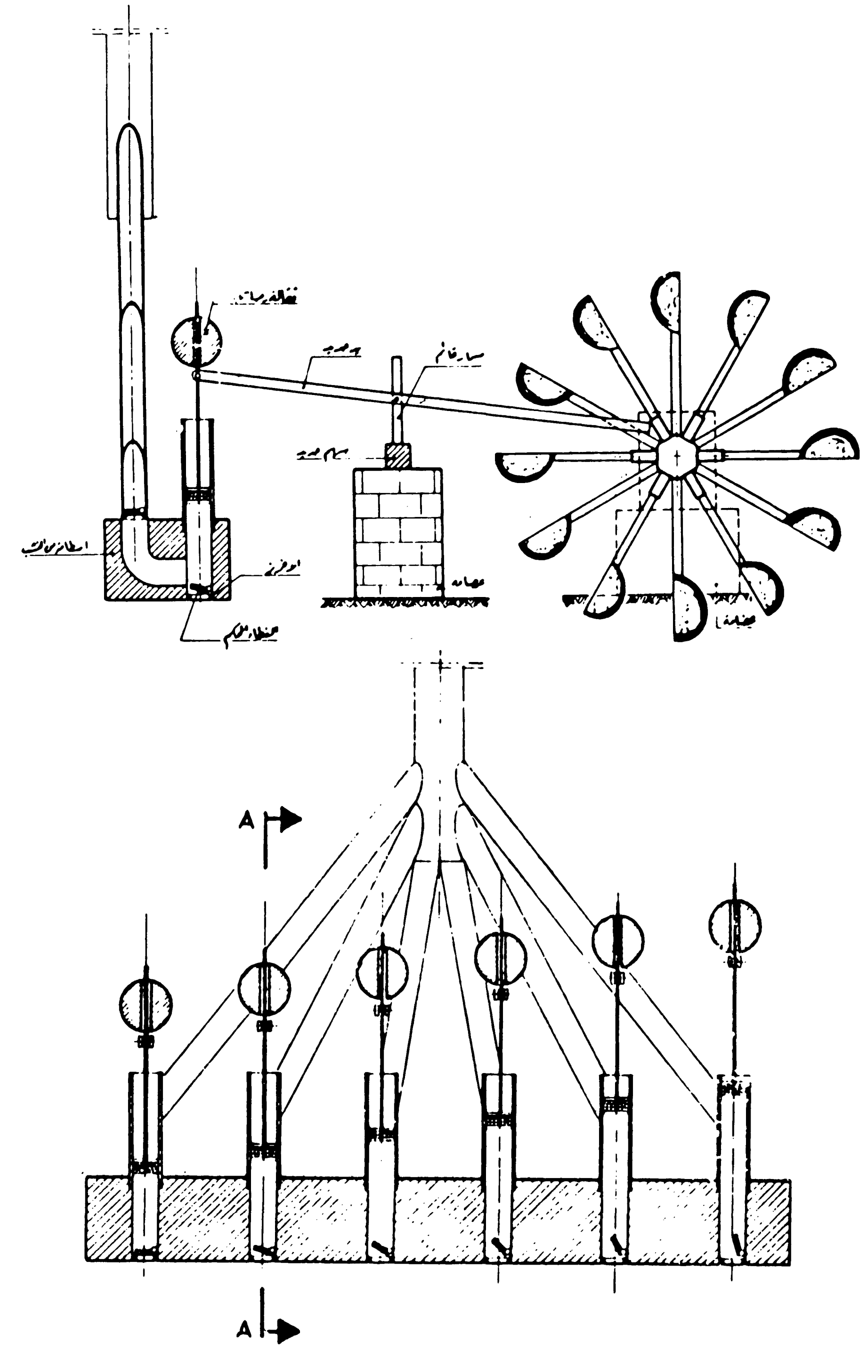



*Figure 22.13*

transmission and the discharge of a steady stream of water from the delivery pipe.

Evidence for the continuation of a tradition of mechanical engineering is provided by a book on machines written by Taqī al-Dīn about the year 966/1559. A number of machines are described, including a pump similar to al-Jazarī's, but the most interesting device is a six-cylinder 'Monobloc' pump. The cylinders are bored in line in a block of wood which stands in the water – one-way valves admit water into each cylinder on the suction stroke. The delivery pipes, each of which is also provided with a one-way clack-valve, are led out from the side of each cylinder and brought together into a single delivery outlet. On the end of each piston rod is a lead weight, and a trip lever is connected by a pin joint to the piston rod just below the weight. Cams on the axle of a water-driven scoop-wheel bear down on the trip levers in succession, raising the pistons for the suction stroke. When the trip lever is released the weight forces the piston down for the delivery stroke (see Figure 22.13). It is worthy of note that Taqī al-Dīn's book antedates the famous book on machines written by Agostino Ramelli in 1588. It is therefore quite possible that there was some Islamic influence on European machine technology even as late as the tenth/sixteenth century.

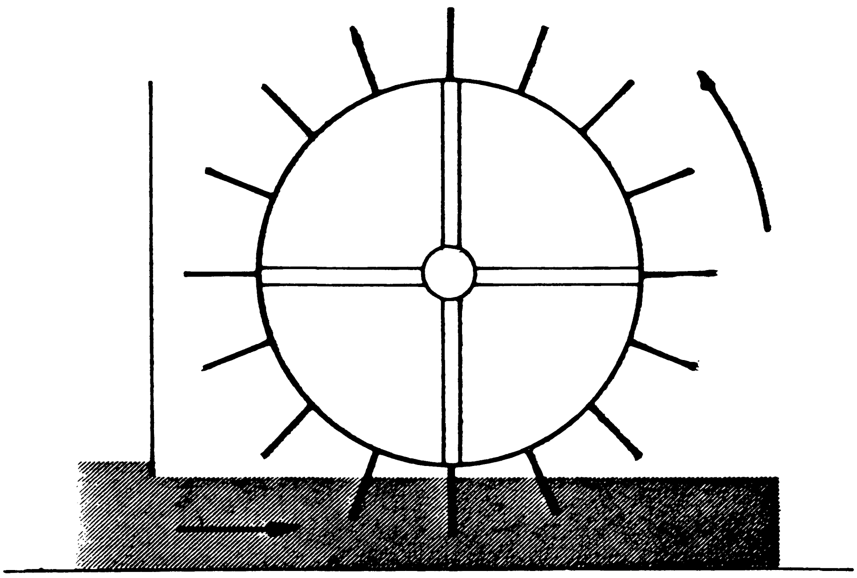


*Figure 22.14*

## Power from water and wind

There are three basic types of water-wheel, all of which had been in use for centuries before the advent of Islam and the question of their origin, and diffusion, which is still unresolved and controversial, need not concern us here. The first – the undershot wheel – is a paddle wheel mounted on a horizontal axle over a running stream (Figure 22.14). Its power derives almost entirely from the velocity of the water, and it is therefore affected by seasonal changes in the rate of flow of the stream over which it is erected. Furthermore, the water level may fall, leaving the paddles partly or totally out of the water. The efficiency of the undershot wheel is not high – perhaps as low as 22 per cent – because so much of the energy is dissipated by turbulence and drag. The fact that it retained its popularity over many centuries is due to the simplicity of its construction and to special measures that can be taken to increase its performance. These will be discussed later.

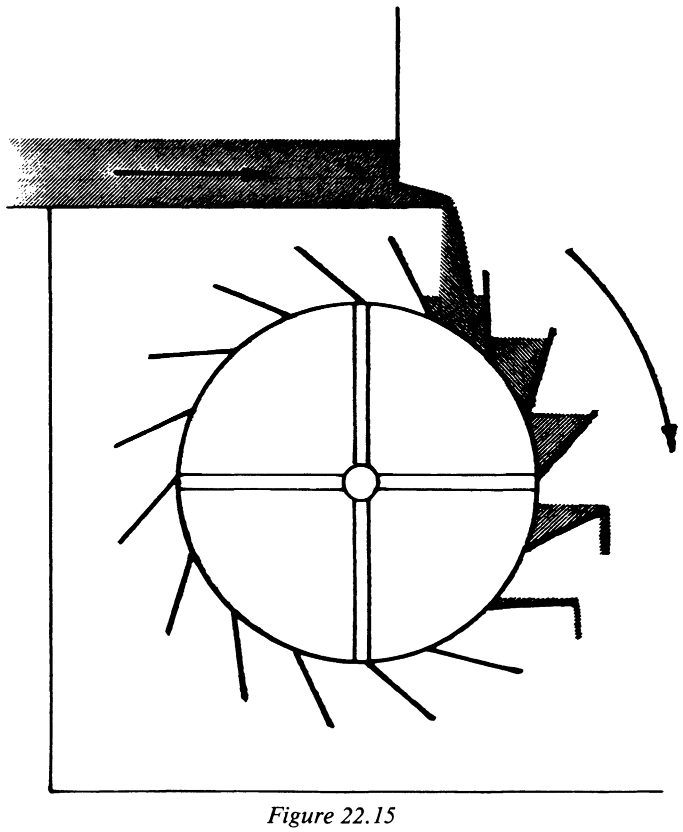


*Figure 22.15*

The overshot wheel is also vertical on a horizontal axle. Its rim is divided into bucket-like compartments into which the water discharges from above, usually from an artificial channel or 'leat' (see Figure 22.15). Its efficiency can be as high as 66 per cent, provided all the water from the leat falls into the buckets and there is no spillage.

When used for corn milling both types of vertical wheels require a pair of gears to transmit the power to the millstones. A vertical toothed wheel is mounted on the end of the water-wheel's axle inside the mill house. This engages a lantern-pinion, whose vertical axle goes up through the floor to the milling room; it passes through the lower, fixed millstone and is fixed

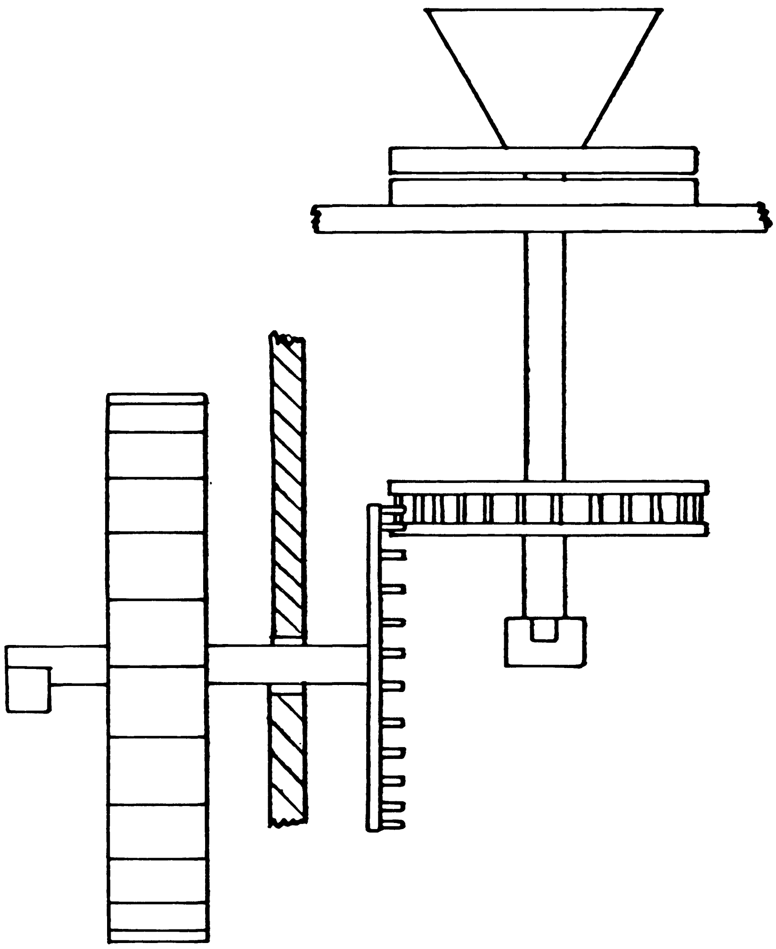


*Figure 22.16*

to the upper, rotating stone. The corn is fed into the concavity of the upper stone from a hopper (see Figure 22.16).

The third type of wheel is horizontal, and can be subdivided into two main types. In the first of these a wheel with curved or scooped vanes is mounted at the bottom of the vertical shaft and water from an orifice fitted to the bottom of a water tower is directed on to the vanes, the flow being therefore tangential and radial (Figure 22.17). The second type is a vaned wheel, also fixed to the lower end of a vertical axle, and installed inside a cylinder into which the water cascades from above, turning the wheel mainly by axial flow. Axial-flow wheels can also be driven by vertical jets of water directed on to them from below. The first sub-type was known in Europe and western Asia by the sixth century AD at the latest. The second appears in an Arabic treatise of the third/ninth century, but is not known to have been used in Europe before the tenth/sixteenth century.

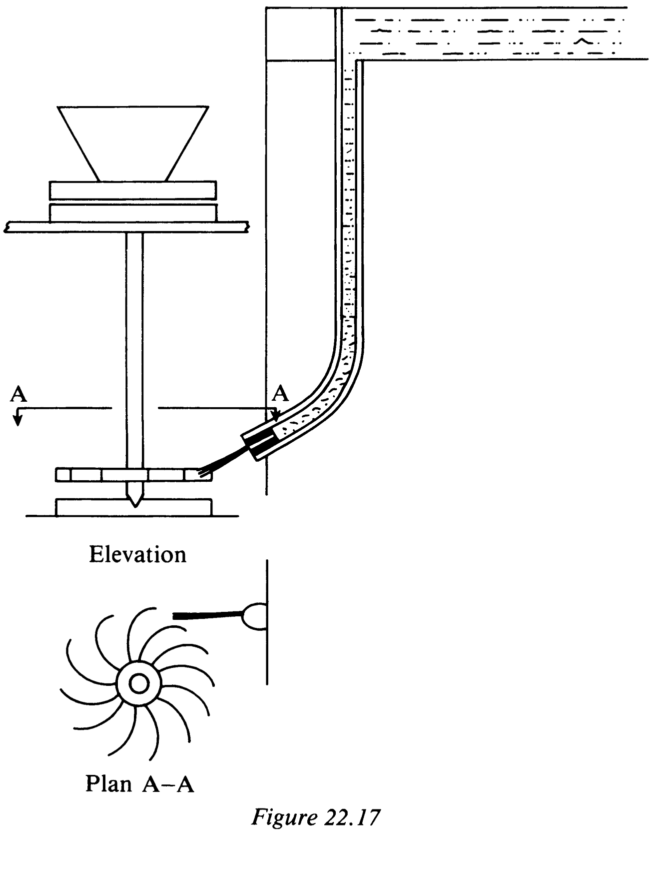



*Figure 22.17*

The Muslim geographers and travellers leave us in no doubt as to the importance of corn-milling in the Muslim world. This importance is reflected not only in the widespread occurrence of mills, from the Iberian peninsula to Iran, but also in the very positive attitude of the writers to the potential of streams for conversion to power. The Tigris at its source, says al-Muqaddasī, would turn only one mill, and al-Iṣṭakhrī, looking at a fast-flowing stream in the Iranian province of Kerman, estimates that it would turn twenty mills. It is as if these travellers were rating streams at so much 'mill-power'. This concern is understandable when we remember that the great cities of Islam such as Baghdad, Fusṭāṭ and Cordoba depended upon the produce of a thriving agriculture to feed their large populations and to provide the finished materials for a thriving commerce. We therefore find that all large urban communities were provided with flour by factory milling installations, either close to the city or accessible to it by good communications. To take but one example: in the fourth/tenth century Upper Mesopotamia was the granary for Baghdad and the corn it produced was ground in large ship-mills moored on the Tigris and the Euphrates. Each mill had two pairs of stones and could produce 10 tonnes of flour in 24 hours. Nothing approaching this scale of corn-milling was known in contemporary Europe.

The ship-mill was one of the methods used to increase the output of mills, taking advantage of the faster current in midstream and avoiding the problems caused by the lowering of the water level in the dry season. Another method was to fix the water-wheels to the piers of bridges in order to utilize the increased flow caused by the partial damming of the river. Dams were also constructed to provide additional power for mills (and water-raising machines) such as the dam built by ʿAḍud al-Dawla over the River Kur in Iran. In the sixth/twelfth century al-Idrīsī described the dam at Cordoba in Spain, in which there were three mill houses each containing four mills. Until quite recently its three mill houses still functioned, but have changed a lot from their original form. Further evidence of the Muslims' eagerness to harness every available source of water power is provided by their use of tidal mills. This application is, of course, not possible in the Mediterranean, but in the fourth/tenth century in the Basra area there were mills that were operated by the ebb-tide. Tidal mills did not appear in Europe until about a century after this.

Water power was also used in Islam for purposes other than corn-milling. In the year 134/751, after the battle of Atlakh, Chinese prisoners of war introduced the industry of paper-making in the city of Samarkand. The paper was made from linen, flax or hemp rags after the Chinese fashion. Soon afterwards paper mills on the pattern of those in Samarkand were erected in Baghdad, the Yemen, Egypt, Syria, Iran, North Africa and

Spain. Without doubt, the raw materials in these mills were prepared by pounding them with water-powered trip-hammers, a method which had long been used in China. Writing about the year 435/1044, al-Bīrūnī tells us that gold ores were pulverized by this method 'as is the case in Samarkand with the pounding of flax for paper'. Water power was also used in the Muslim world for fulling cloth, sawing timber and processing sugar-cane. (It is interesting to note that the transfer of technology between China and Islam was a two-way traffic; according to Marco Polo, the Muslims taught the Chinese how to refine sugar.) It has not yet been established to what extent industrial milling in Europe was influenced by Muslim practices. A likely area of transfer is the Iberian peninsula, where the Christians took over, in working order, many Muslim installations, including the paper mills at Jativa.

Windmills were probably known in Seistan (the western part of modern Afghanistan) before the advent of Islam. According to al-Masʿūdī a Persian claimed to the Caliph ʿUmar I that he was able to build a windmill. ʿUmar made him substantiate his claim by building one. Mills in Seistan are mentioned by the Arab geographers of the fourth/tenth century, but the first full description occurs in a book written about the year 669/1271. These were not the European type of windmill with a horizontal axle and a pair of gears. The mills were supported on substructures built for the purpose, or on the towers of castles or on the tops of hills. They consisted of an upper chamber in which the millstones were housed and a lower one for the rotor. The axle was vertical and it carried twelve or six arms covered with a double skin of fabric. The walls of the lower chamber were pierced with funnel-shaped ducts, with the narrower end towards the interior in order to increase the speed of the wind when it flowed on to the sails. This type of windmill spread throughout Islam, and to China and India. In medieval Egypt it was used in the sugar-cane industry, but its main application was to corn-milling.

For all types of mills, the quality of the millstones has always been important. They must be hard but of homogeneous texture, so that pieces of grit do not become detached and get mixed with the flower. The stone from certain localities was therefore particularly prized for milling purposes. In the area of Majjana, in modern Tunisia, they cut millstones from the nearby mountains and exported them all over North Africa. They were said to last for a man's lifetime without treatment or dressing, because of their solidity and the fineness of their grains. The black of al-Jazīra – i.e. Upper Mesopotamia – was called 'the stone of the mills'. It was the stone used for the mills that supplied Iraq with flour. It had no equal; a single millstone made from this material cost about 50 dinars. Stone for the mills of Khurasan was mined from the hills near the city of Herat.

## FINE TECHNOLOGY

The expression 'fine technology', applied to earlier times, embraces a whole range of devices and machines, with a multiplicity of purposes: toys and automata, water-clocks, fountains and astronomical instruments. Some were designed to delight and amuse, some to tell the time and some as aids to scientific investigation. What they have in common is the considerable degree of engineering skill required for their manufacture, and the use of delicate mechanisms and sensitive control systems. A characteristic feature of many of these devices, also, is the use of biological and celestial simulacra, which can be interpreted as reflecting an urge to make mechanistic representations of physical phenomena. Nevertheless, it would be wrong to invest all automata with a special significance in the development of man's view of the world. Many were simply ingenious toys, and for this reason some historians, far from detecting any significance in these devices, have dismissed them as trivial. This is about as sensible as dismissing modern communications technology because many television programmes are frivolous or banal. Many of the ideas developed in the construction of ingenious devices were later to enter the vocabulary of mechanical technology.

When we look into the origins of fine technology, we inevitably find our attention directed to the Hellenistic world and, in particular, Alexandria. Thus we find that the first complex water-clock and the first musical automaton are both attributed by Vitruvius to Ctesibius, an Egyptian engineer who worked in Alexandria about 250 BC, and the first major treatise on ingenious devices was composed by Philo of Byzantium a contemporary of Ctesibius. Philo's work was continued and extended by Hero of Alexandria, who flourished in the middle of the first century AD. The origins of the astrolabe can be firmly placed in the school of Alexandria. It was almost certainly known to Ptolemy and was described by Theon of Alexandria (*c.* 350 AD), whose writings are preserved in the treatise of Severus Sebokht, composed in Egypt before 660, i.e. a few years after the Arab occupation of the country. It can be shown conclusively that this tradition was not broken by the advent of Islam. A number of Greek treatises were translated into Arabic – indeed, in several cases the Arabic versions are the only ones to have survived. These treatises were known to the Islamic writers and engineers, who freely acknowledged the achievements of their predecessors. The transmission was also sometimes by means of what we would call archaeological methods. It is known, for example, that monumental water-clocks were built in Syria from classical times, through the Byzantine period and into the Muslim world. It would therefore have been possible for these clocks to be inspected and copied by later engineers.

What is more likely, however, is that the skill was handed down from father to son, so remaining in the family, who in the course of time became Arabic-speaking Muslims. As the centuries passed, fine technology became a recognizably Muslim profession and while an engineer might refer to Greek works, he could find most of his inspiration in the works of his Muslim predecessors. A similar process can be observed with other sciences and technologies.

It is not easy in the space available to demonstrate how the Muslim engineers were different from and in some ways superior to their Hellenistic predecessors in the field of fine technology. This can probably best be done by considering a few of the more important Islamic works, placing emphasis upon their innovative features. The Banū Mūsā were three brothers – Muḥammad, Aḥmad and al-Ḥasan – who were members of the courtly circles of the Abbasid Caliph al-Ma'mūn (198/813–218/833) and his successors. This was the period that witnessed the first flowering of Arabic science, both in the translation of Greek and Syriac works into Arabic and in original scientific and technological works, and much of this activity was carried out under the direction and patronage of the Banū Mūsā. They were also scientists and engineers in their own right and wrote about twenty treatises, only two of which are known to have survived. One of these, *The Book of Ingenious Devices* (*Kitāb al-Ḥiyal*), written in Baghdad about 235/850, is our present concern. It contains descriptions of a hundred devices, most of which are trick vessels, together with self-feeding and self-trimming lamps, a gas mask for use in polluted wells and a mechanical grab. The trick vessels exhibit a bewildering variety of effects, for example:

> Model 26. A jar with an outlet pipe: during inpouring of a liquid the pourer can, according to choice, allow the liquid to discharge, or prevent its discharging.
> Model 43. A jar with a tap, into which three different liquids can be poured without mixing. When the tap is opened the liquids discharge in the sequence in which they were poured in.
> Model 77. A basin beside a closed reservoir. When moderate quantities of water are taken from the basin, like quantities run into it from a pipe at the bottom of the reservoir; if, however, a large quantity is taken no replenishment occurs.

These effects, and many others, were produced by the ingenious combination of a number of hydraulic and mechanical components, two of which are shown in Figure 22.18. Figure 22.18(a) shows a double concentric siphon: pipe *bd* passes through plate *f* which divides the upper chamber from the lower, the joint being airtight. Pipe *a-cc* is placed over end *b* of pipe *bd* and held to it by soldering pieces of copper wire between the two pipes. End *a* of this pipe is closed. Another wide piece of pipe *e-gg*, its end

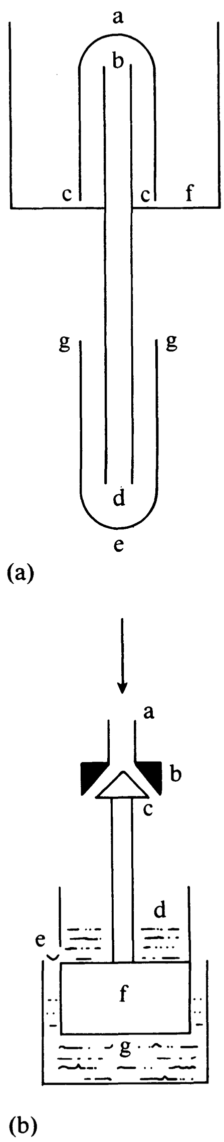



*Figure 22.18*

*e* closed, is fixed over end *d* of pipe *bd*. The effect of introducing this device into a flow system is to create an airlock once the flow of liquid is interrupted, so that the flow cannot be restarted except under certain conditions. Onlookers could therefore be startled by unexpected events. The double concentric siphon does not occur in any of the Greek writings nor, as far as we know, in any Arabic work except the Banū Mūsā's book. The fluid mechanics of its operation are surprisingly complex.

The second mechanism is shown in Figure 22.18(b). Seat *b* of a conical valve is soldered to the end of pipe *a*, and plug *c* of the valve is soldered to the end of a vertical rod, the other end of which is soldered to the top of float *f*. Above the float and integral with it is the small tank *d* which has a small hole *e* in the bottom of one of its sides. The float rests on the surface of the water in the slightly larger tank *g*. It works like this: water is poured in at *a* and runs through the valve into tank *d*; the weight of the liquid in tank *d* stops the valve-rod from rising and so the valve remains open. When pouring is stopped tank *d* empties into tank *g* through hole *e*, float *f* rises and the valve closes. No further inpouring can then take place. Conical valves do not appear in the works of Philo and Hero, and in fact there is only one known use of this component before the Banū Mūsā. These valves were made by casting the plug and seat together in a single mould, the material nearly always being bronze. Plug and seat were then ground together with emery powder to a watertight fit.

A distinguishing feature of the Banū Mūsā's work is therefore their confident use of conical valves as integral parts of flow systems. More generally, they show an astonishing empirical mastery of the use of small variations in hydrostatic and aerostatic pressures to produce a variety of effects. Although their work was well-known in the Muslim world for centuries after their time, none of their successors ever attempted to emulate them. They had, in fact, taken the subject to its limits with the materials and techniques then available, and nothing similar was done until the introduction of pneumatic instrumentation in modern times. (Any connection between the two is, of course, most unlikely.) It may well be asked why anyone should exercise such ingenuity for such trivial results. There is no simple answer to such a question, but we should first emphasize that, as well as being eminent scientists, the brothers were also practical engineers who undertook public works projects in Iraq. The Ingenious Devices were therefore probably a form of recreation for them and a means of amusing the Caliph and his companions. It is not uncommon, however, for men of inventive minds to explore a subject as far as they can, without paying too much attention to the objectives.

A most important treatise was written in Muslim Spain in the fifth/eleventh century by a certain al-Murādī. Unfortunately, the only known manuscript of the work is so badly defaced that it is impossible to deduce from it precisely how any of the machines was constructed. Most of the devices were water-clocks, but the first five were large automata machines that incorporated several significant features. Each of them, for example, was driven by a full-size water-wheel, a method that was employed in China at the same period to drive a very large monumental water-clock. The automata were of the type that were common in water-clocks, for example a set of doors in a row that open at successive intervals to reveal jackwork figures. The text mentions both segmental and epicyclic gears. (In segmental gears one of a pair of meshing gear-wheels has teeth on only part of its perimeter; the mechanism permits intermittent transmission of power.) Although the illustrations are in other respects quite incomprehensible, they clearly show gear-trains incorporating both these types of gearing. This is extremely important: we have met simple gears in mills and water-raising machines, and we know that complex gears were used in manually operated astronomical instruments in Hellenistic times, but this is the first known case of complex gears used to transmit high torque. It is also the earliest record we have of segmental and epicyclic gears. Sophisticated gears for transmitting high torque first appear in Europe in the astronomical clock completed by Giovanni de' Dondi about AD 1365.

Al-Jazarī completed his magnificent book on machines in Diyar Bakr in the year 602/1206. This is the most remarkable engineering document to have come down to us, from any cultural area, until the Renaissance. In one respect it is unique: it was written at the wish of al-Jazarī's master so that a record of the fragile devices could be available for succeeding generations of craftsmen, long after the devices themselves had perished. Each of the fifty chapters – text and illustrations – was therefore composed with detailed instructions for manufacture, so that the machines could be reconstructed by later craftsmen, in accordance with al-Jazarī's declared intention. We know that he was successful in this aim because several of his devices including a monumental water-clock, have been constructed by modern craftsmen working from al-Jazarī's instructions. The works of other writers, while they often describe the operation of the machines quite adequately, give only the sketchiest details of construction. In many cases this was because they were not themselves the craftsmen who actually made the devices or, if they were, they preferred to keep the key skills of their trade secret. We also have to remember that many craftsmen were illiterate and hence unable to commit their results to paper. Al-Jazarī's willingness and ability to communicate the knowledge gained by training, experience and informed experiment therefore endow his work with immense value.

Al-Jazarī was an engineer who took pride in continuing a long tradition of mechanical technology, and his work may in many respects be regarded as the epitome and the summit of the Islamic achievement in this field. With one or two notable exceptions, such as the complex gear-trains of al-Murādī, it is safe to assume that he dealt with most of the machines that had been known to his predecessors, while introducing innovations and improvations of his own. Indeed, he often acknowledges the work of earlier engineers, such as Archimedes or the Banū Mūsā, in connection with a particular technique or type of machine, describes the earlier construction accurately and then tells us how he improved upon it. For instance, a certain type of flow regulator was used in water-clocks by both Hellenistic and Muslim engineers. Al-Jazarī found by experiment that it was inaccurate, and describes how he made an accurate instrument by carefully calibrating a small orifice to produce correct rates of flow under various heads of water.

One example will have to suffice to give some idea of al-Jazarī's methods and the type of device he constructed. This is the water machinery and some of the associated mechanisms from his third and fourth water-clocks. These were driven by the submersible bowl or *tarjahar*, a device that was normally used for timing the period of allocation of irrigation water to farmers. These two clocks are the only examples we have of the adaptation of the *tarjahar* for timekeeping, and it seems likely that this system was al-Jazarī's own invention. Figure 22.19 shows the basic principles; it would be impossible to describe either of the clocks fully, since they had a number of automata together with the mechanisms for activating them, some of them very ingenious.

The bowl *a* with a calibrated orifice in its underside rests on the surface of the water in tank *n*, to which it is connected by the three flat pin-jointed links *b*. A rod is soldered across a diameter of the bowl, with hole *k* in its centre. At the top of the clock, supported on four columns, is the 'castle', a square brass box with a detachable dome. Inside the castle is a ball-release mechanism (not shown) from which a channel leads to the head *f* of a bird. The tail of the serpent, in effect a pulley, rotates on an axle that rests in bearings in transoms fixed between each pair of columns. The open mouth of the serpent is just below the head of the bird. A light chain *d* runs from the underside of the bowl to a staple in the tail of the serpent. A wire *h* is tied to hole *k* and to the ball-release. At the beginning of a time period – an hour or half an hour – the empty bowl is on the surface of the water. It sinks slowly until at the end of the period it suddenly submerges. Wire *h* operates the ball-release, and a ball runs into the bird's mouth and out of its hinged beak into the mouth of the serpent. The serpent's head sinks, and chain *d* lifts the bowl, which tilts due to the combined action of the chain and links *b* and discharges all its contents. The ball drops from the serpent's mouth on to a cymbal, and the serpent's head rises to its previous position. The empty bowl is again horizontal on the surface of the water, and the cycle re-starts. This is therefore a closed-loop system, since the clock will continue working as long as there are balls in the magazine. The concept of continuous operation occurs elsewhere in al-Jazarī's work; in his first clock, for example, the head of water over the orifice is kept constant by a hydraulic feed-back control system.

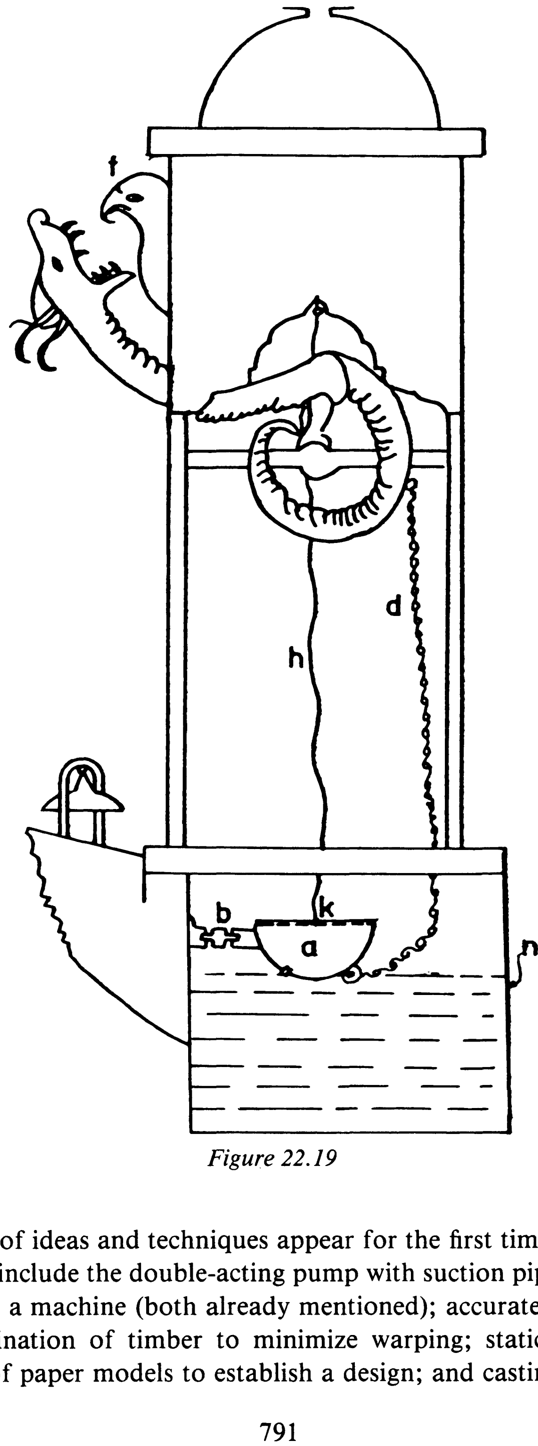



*Figure 22.19*

A number of ideas and techniques appear for the first time in al-Jazarī's work. These include the double-acting pump with suction pipes and the use of a crank in a machine (both already mentioned); accurate calibration of orifices; lamination of timber to minimize warping; static balancing of wheels; use of paper models to establish a design; and casting of metals in closed mould-boxes with green sand. There is also an indication that he knew of a method for controlling the speed of rotation of a wheel by an escapement of some kind. This is very significant when we consider a clock described in a Spanish work compiled in AD 1277, in which all the chapters are translations or paraphrases of earlier Arabic works. The clock consisted of a large drum made of walnut or jujube wood tightly assembled and sealed with wax or resin. The interior of the drum was divided into twelve compartments, with small holes between the compartments through which mercury flowed. Enough mercury was enclosed to fill just half the compartments. The drum was mounted on the same axle as a large wheel powered by a weight-drive wound around the wheel. Also on the axle was a pinion with six teeth that meshed with thirty-six oaken teeth on the rim of an astrolabic dial. The mercury drum and the pinion made a complete revolution in 4 hours and the astrolabic dial made a complete revolution in 24 hours. Clocks incorporating this principle are known to work satisfactorily, since many of them were made in Europe in the seventeenth and eighteenth centuries. This type of timepiece, however, with its effective mercury escapement, had been known in Islam since the fifth/eleventh century – at least 200 years before the first appearance of weight-driven clocks in the West.

Before concluding this review of fine technology in Islam, we can mention briefly the subject of instrument making for astronomical purposes. The astrolabe was the astronomical instrument *par excellence* of the Middle Ages; from its Hellenistic origins it was brought to perfection by Muslim scientists and craftsmen. Essentially it consists of a circular plate inside a raised annulus that is divided into degrees, the annulus being soldered to the rim of a base-plate. The first plate is engraved with the lines of azimuth and altitude for the latitude of the observer. Turning on a central pin above the plate is the rete or spider, made of open metalwork. This is essentially a star map, the principal fixed stars appearing as holes or gemstones; there is also a circle for the sun's ecliptic. Rotating above the rete was an alidade. Both plate and rete were marked out by stereographic projection. The instrument was usually made of brass (see Figure 22.20). A number of astronomical problems, which otherwise have to be solved by tedious computation, can be solved very quickly by using the astrolabe. It has been established that the first European treatises on the astrolabe were of Arabic inspiration and were written in Latin at the beginning of the fifth/eleventh century in the abbey of Ripoll in Catalonia. From this centre the knowledge of the instrument was diffused to the rest of Europe.

Other computing instruments were devised in the Muslim world in the later Middle Ages, perhaps the most important of these being equatoria, which were invented in Muslim Spain early in the fifth/eleventh century.

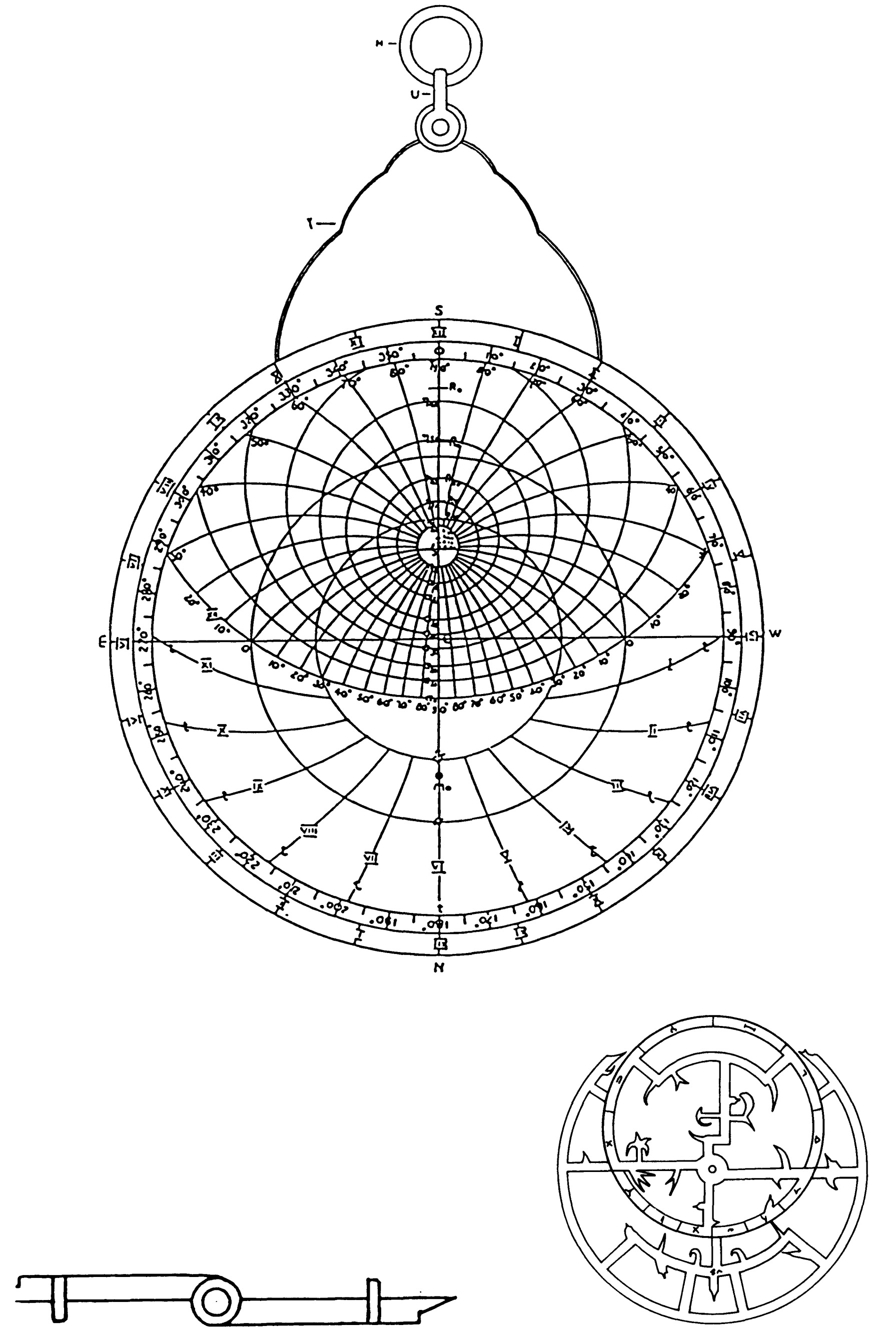



*Figure 22.20*

The objective of the equatorium was the determination of the longitude of any one of the planets at a given time. This was done by constructing to scale and by mechanical and graphical means the Ptolemaic configuration for that particular planet at the given instant. As with the astrolabe, knowledge of equatoria was diffused into Europe from the Muslim world.

We have seen that a large array of machines, techniques, mechanisms and components was available to Muslim engineers. Of equal importance, to the development of mechanical technology, was the pre-occupation of engineers like the Banū Mūsā and al-Jazarī with sophisticated methods of automatic controls, since a key element in any machine is the means for controlling the release of energy. Apart from the case of astronomical instruments, however, we have no firm evidence for the transmission of this body of knowledge into Europe. It seems most unlikely that the Muslim ideas that appeared in Europe from the later Middle Ages onwards were all reinventions, and we must therefore hope that further research will establish some of the ways by which this knowledge was diffused from Islam. In the absence of evidence we can build up, using a specific case, a reasonable theory of diffusion.

The invention of the mechanical clock is one of the most significant events in the history of technology. It was the first machine to use controlled gravitational force as motive power and it incorporates a number of ideas that were to be of importance in the development of machine design. Its key mechanism is the mechanical escapement, which controls the speed of descent of a heavy weight. Apart from this mechanism, all the features of the early mechanical clocks are to be found in the monumental water-clocks of Islam: complex gear trains; arrays of automata; and weight-drives. The idea of an escapement is also present in the mercury clocks and in the hydraulic controls used to make heavy floats descend at a slow, steady rate. We know that the Christians in Spain learned about Muslim water-clocks, not only by the translation of Arabic works into Spanish but also by the inspection of actual clocks. For example, two monumental water-clocks built by the astronomer al-Zarqāllu on the banks of the River Tagus in Toledo were still working when the Christians entered the city in AD 1085. The possibility of transmissions elsewhere, notably during the Crusaders' occupation of parts of Syria, cannot be discounted, although it is likely that Spain was the main locus for transmission.

The chain is completed by two pieces of information about European clockmaking. The first is that there was a substantial advance in the techniques of hydraulic timekeeping in the fifth/eleventh century, accompanied by an increased diffusion of the new methods and techniques. The second is a treatise written by Robertus Anglicus in 1271, in which he says that the clockmakers – i.e. the makers of water-clocks – were trying to solve the problem of the mechanical escapement and had almost reached their objective. The first effective escapement appeared a few years later. The evidence, circumstantial though it is, points strongly to an Islamic influence upon the invention of the mechanical clock. It is to be hoped that, as research proceeds, firmer evidence for the transmission of Islamic fine technology into Europe can be provided.

## NOTE

Much of the information on Islamic engineering, apart from that to be found in the major Arabic treatises, occurs in scattered articles and in reports in the works of Muslim geographers, travellers and historians. Details of these articles and reports will be found in my *Arabic Water-clocks* and *A History of Engineering in Classical and Medieval Times*. A great deal of information is to be found in *The Encyclopaedia of Islam*, second edition; this should be sought not only in the entries dealing with specifically technical subjects, but also under place-names and the names of scientists and engineers.

# 23

# *Geography*

ANDRÉ MIQUEL

The history of Arabic geography hinges on two major events: the foundation of the Abbasid Caliphat of Baghdad, in the middle of the second/eighth century, and the appearance in force of the Turks on the scene of the Muslim world, four centuries later. But first, a question: what should be understood by the term geography? Quite obviously, not at all what we include today in this word, with multiple meanings besides. As regards the Arabs, and throughout the Middle Ages, the variety is out of place. And yet, looking at things as a whole, the texts that are offered to us all comply, more or less, with the definition that is found inscribed, etymologically, in the Greek word: the description of the earth.

The first act, therefore, is with the Abbasid Caliphs of Baghdad, the Iraqi cross-roads widely open to Arabic, Muslim or pre-Muslim, Persian, Indian and, finally, Greek influences through translations, directly into Arabic or through the intermediary of Syriac. In this great movement of transmission of civilizations which was extensive under the Caliphat of al-Ma'mūn (813–33 AD) geography held a place of honour. One name dominated on the Greek side: Ptolemy. Another dominated on the Arabic side: Muḥammad b. Mūsā al-Khwārizmī, who inherits both Greek and Indian. And one name designates it: the Arabic reproduction of the Greek word, *jughrāfiyā*. It is essentially a cartographic science, which features in two areas – representation of the earth and representation of the sky, still closely linked, therefore, with astronomy. Very quickly nevertheless the new world born from Islam and Baghdad is going to make its mark on it. The map received from Ptolemy will be corrected, completed by the lands that Greek geography does not know well and which form henceforth part of a domain that Islam knows infinitely better: its own.

Thus is born, under the pen of the first Arab geographers, started by the leader al-Khwārizmī, what is called *ṣūrat al-arḍ*, the 'figure of the earth', a new form of the heritage of *jughrāfiyā*. Our world is portrayed there in the form of a sphere divided, in its northern half, into seven longitudinal bands from the equator: the *iqlīm* (from the Greek *klima*) reviewed and corrected according to the new history and the new data on knowledge of the world, latitude and longitude locating the principal mountains, rivers, seas or towns on the picture.

At almost the same time was born what one could call the geography of state officials, again directly linked to the arrival of the Caliphat of Baghdad but in other ways. The great name here is that of Ibn Khurdādhbih, who composed in 232/846 the first version of his *Book of Roads and Kingdoms* (*Kitāb al-masālik wa-l-mamālik*), the title of which, as we can see, indicates other perspectives. The author himself also is very representative of the developments that had arisen. Iranian by origin, expressing himself in Arabic, he belongs to the body of imperial officials, and more specifically to one of the most important services of the central administrative machine, the postal service (*barīd*), responsible for the organization of couriers, for the collection of information, for briefing of the liaison between Baghdad and the more distant provinces.

Three imperatives dominate this geography, three themes which constitute the subjects to know about for power: tax, the situation on the frontiers, the roads with their distances and their stages. Thus, the work of Ibn Khurdādhbih, at the same time that he was opening up descriptions of certain neighbours of Islam, integrates into geographical knowledge concrete data regarding the state of different countries of Islam, their precise place, their wealth. But already another aim is taking form, larger and in two directions. On the one hand, it is intended not to leave out any data relative to the Muslim world of the whole earth, and in this spirit the book will be opened to some of the fundamental data of the *ṣūrat al-arḍ*; on the other hand, some of the themes considered to constitute the general culture (*adab*) of the 'honest man' of the time are evoked: great kings of the earth, the evocation of Rome, the wonders of the world, the legendary people of Gog and Magog. . . . The development of the book in this sense is quite clear between the first version and the second, written some forty years later. It was necessary, from all the evidence, to put the book in fashion, to adapt it to the mood of the time, which carried other themes, other desires. Which?

Those of travel. A series of texts, unfortunately lost or preserved in other works as scraps, simple echoes, pass on to us the adventures, often embellished, of the unrepentant adventurers or officials, always those, sent for information beyond the frontiers: towards Constantinople, the depths of Central Asia and even the Norsemen of Jutland. Nevertheless, to all the domains it is the sea which carries them, the open sea which leads the merchants to the Far East: she inspires the anonymous collection called

*Account of China and India* in which mariners' tales appear alongside precise facts, often of highest quality, on the countries visited. One model, which will be widely exploited, appropriated, developed in the sense just of the marvellous, started with Sindbad of the *Thousand and One Nights*.

Without doubt one will say that we are far here from what is understood as geography. This is undeniable, and yet. . . . On the one hand, if we speak of geography not in terms of science, or of genre, but as knowing in the strict sense, what is undeniable is the considerable contribution that these texts, freed from their more or less marvellous elements, bring to a better knowledge of the earth. Roughly forty years after the second version of the work by Ibn Khurdādhbih, one of the members of a Caliphian embassy, Ibn Faḍlān, will leave us a remarkable account of his journey to the land of the proto-Bulgarians settled at the confluence of the Volga and the Kama. Another reason not to treat these texts with the contempt that geography in the strict sense would inspire is the journey itself, understood as a prime source of information and extension, overstepping bookish knowledge; we shall come back to this. And finally, a last reason is the integration of these data to the global treasure of the *adab*, from which geography, real geography this time, or at least one of its forms, will draw its inspiration.

The *adab* demands some explanation. It is at the same time a spirit, a method and a code. It poses the necessity, for the honest man, for a broad and non-specialized knowledge passed on in works combining the serious and the relaxed: to learn through enjoyment if one wishes. The field traced, as we have just said, has no limits: we use any method we can, even science on the condition that we stick to general notions or to points of detail, as we understand it, but always outside the spirit and vocabulary of technicalities. Thus, around the themes that it will be good form to know, a circle of the initiates will be built up who will launch, exchange or develop a debate becoming, from a control of obligatory knowledge, the mark of belonging to an elite. Spirit, method and code, we would say. Or, if one prefers, style of expression, knowledge and social passport.

Viewed from the angle that is occupying us, that of geography, the *adab* can play its role in three ways, all three of which take place at the turning point of the ninth–tenth centuries of our time. The data, or at least some data, from the *ṣūrat al-arḍ*, from administrative geography and journeys, are integrated into some encyclopedias the content of which tries to resemble the knowledge of the honest man. Example: *The Precious Finery* (*al-Aʿlāq al-nafīsa*) of Ibn Rusteh (about 290/903). On other occasions, this style of encyclopedia, but in a condensed form, is presented as the preface to a work of determined, precise aim: thus did Masʿūdī in his famous *Prairies of Gold* (first half of the tenth century), where the history of the world since its creation, the description of the earth and its great peoples, the evocation of some animal and vegetable celebrities, introduce to the body of the work a history of Islam since its origins until the time of the author. In one and the other case, even if the ideas of geography only represent one element among others, the main point is that they are seen as necessary to the corpus of the *adab*, and that this *adab* in turn is considered as necessary to every aim. But as important as this treatment of geography is for cultural history, for the history of geography itself it yields, and by far, to a more close association between it and the *adab*, an association where geography this time leads the game. The third possible way that is mentioned above also occurred at the turning point of the ninth–tenth centuries and bears the name Ibn al-Faqīh.

It is not so much, at first glance and even after reading, the content which changes. The book by Ibn al-Faqīh, composed about 290/903, in effect collects, without apparent order, all which could constitute the store of knowledge, very unusual, of the cultured man. One finds or refinds there, by chance, a few famous monuments, some wonders of the animal and vegetable world, some extracts from the *ṣūrat al-arḍ*, some sayings, some philological or other controversies, the product of land taxes, of history, Islam, Arabia, Alexandria, Iran, the sages of Greece, the talismans of Apollonius of Tyana, the evocation of foreign peoples and the accounts of sailors on the royal commerce route of the Far East. The main part borrowed, gleaned here and there, pillaged from all that Ibn al-Faqīh was able to read, he was thus able, it could be said in passing, to preserve for us some or other work that has disappeared.

But it is not that that is important: in fact we knew that already. What is new is the very title of the book, *The Countries* (*Kitāb al-buldān*), which indicates that some changes have occurred. For the first time, the given of the *adab* is subsumed to geography, which offers the chance and the frame for its collection: strange and disorganized as it is to our eyes, this information is classed country by country. The encyclopedia is no longer superimposed on to one of the pieces of knowledge that make up its corpus, it is that knowledge, geography in space, that now dictates the distribution of its contents. Through which one sees that the country, meeting place of all or almost all possible themes, acquires its autonomy, and geography with it – or at least a certain type of geography – as a result. Diversity is no longer a general rule which makes everything abide by its law, it becomes the mark of each country taken one by one, in the reality that fashioned it in the course of its history and continues to fashion it in some aspect or other of the picture that it presents in the lifetime of the author.

The influence of Ibn al-Faqīh is going to act in a decisive manner, although for us unforeseen. Diverted in every case. Literally, his work will not have direct descendants, and the project of a geographical *adab*, realized with him, will die with him: geography could very well continue to look for a definition in relation to the general culture of his time; never again will she pretend to enclose it in her framework, save for the case, examined later, of dictionaries. It is therefore, we would say, in another way that Ibn al-Faqīh will mark geographical literature. Even when his successors will be brought to criticize him, his geography and his method, they can do no less, precisely, than cite him, borrow from him sometimes. In the context of the *adab*, of this cultural system where knowledge and the invocation of the authorities weigh so heavily, where an Ibn al-Faqīh, by the law and the code game, is led to assume the role of godfather, who sees only that one can call up at least the best part of his talent, i.e. the plan and birth of a geographical genre in the true sense of the term? Until him, geography only existed, in an individualized form, through the *ṣūrat al-arḍ*, which because of its technical nature was only interesting to scholars, and in Baghdad was only an imported, foreign bloom. Daughter of Greece, acclimatized, improved without doubt, but from elsewhere. And all the rest was only geography on occasions: the officials – an Ibn Khurdādhbih already cited, but in particular Qudāma b. Jaʿfar, who prepared his book at the time when Ibn al-Faqīh published his – could well have dealt with geographical themes; their works do not bring up less of an other genre, that of the administrative encyclopedia, which also made profit of the themes of general culture, ideas about law also, of history and even stylistics for the production of documents. And seemingly through the journeys, which touch on geography but are not it. Now in contrast, with Ibn al-Faqīh the road is clear, the horizon free: one will make, perhaps, a geography other than its own, but whatever the circumstances one can do geography and claim the right to present it as a work which owes nothing to the others. It is only due to this more or less remote, more or less acknowledged, reference that Ibn al-Faqīh will remain one of the greatest.

From the middle of the fourth/tenth century, therefore, a revolution occurred. Four names give emphasis to the arrival of this new geography: al-Balkhī, al-Iṣṭakhrī, Ibn Ḥawqal and al-Muqaddasī. Almost a school, at least for the first three, because al-Iṣṭakhrī took up and developed the book by al-Balkhī, Ibn Ḥawqal doing the same for al-Iṣṭakhrī. At the outset, it was a cartography of the countries of Islam, each map being accompanied with a commentary. But with al-Iṣṭakhrī and Ibn Ḥawqal, the proportions are going to reverse, the commentary becoming the true text, description, in short the body of the work, the map being no more than an accompaniment: an aim that al-Muqaddasī will also follow. First change: the map breaks with the old Ptolemaic traditions, more or less modified, and arranges itself resolutely according to the habitual way in Iran. It is a question of representing less the cartographical reality of the different countries of Islam than the geometrical image of their representation, reduced to a few simple forms: rectangle, circle, triangle, helix and crescent, themselves expressly related to cover, disc, hollow, passageway and the arch called *ṭaylasān*, making in effect, once deployed, the image of the crescent. The intention is therefore clear: to render the earth appreciable by drawing a concrete image, outside maps or schemas drawn up by scholars. The text, also, carries the mark of this willingness to stick to the real.

This geography of the fourth/tenth century innovates through its subject, its spirit and its technique. The subject will be the Muslim domain and that only. The *ṣūrat al-arḍ* appears only as an introduction to the work, a presentation of some bits of information on the earth in general, and the evocation of foreign peoples, when it exists, takes place in the form of short excursuses, of excursions rather, beyond the frontier lands. But nothing of all this jeopardizes the aim and equilibrium of the work, this impressive bloc made up by the Muslim domain (*mamlakat al-Islām*) and presented through the large countries which compose it.

One could ask why a project quite evidently so natural – talking about the country which is your own – came to happen so late. Two reasons without doubt explain this. The first has extra-geographical goals admitted or not by the authors or, if one prefers, to the readers whom one has in view. The merchants first, of whom al-Muqaddasī thinks above all others: from this point of view, through the description of towns and their resources, itineraries, information on money or the systems of weights and measures, the book will be first a technical guide for the perfect tradesman. But there are also others, the 'greats' as the same al-Muqaddasī said and, as he thinks in secret, Ibn Ḥawqal more than any other. This second half of the fourth/tenth century sees in effect the spreading of a formidable fight for influence between the two rival caliphates, Sunni and Shiʿite, of Baghdad and Cairo. Now, if the first, at least theoretically and at least throughout the eastern half of the empire, can count on its officials to be familiar with the state of the provinces, the caliphate of Cairo for these territories that he covets must resort to agents for information, missionaries speaking more or less openly and of whom Ibn Ḥawqal represents exactly the type. Thus the old project of administrative geography arrives at its perfect systematization: the three major themes that it deals with, to know the tax, the roads, the frontier, are found here in a perspective infinitely more vast, which tries not to leave in the shadows any of the local aspects of the countries of Islam. In this sense, the geography of the second half of the fourth/tenth century is the full-blown daughter of authors such as Ibn

Khurdādhbih or Qudāma b. Jaʿfar, already cited, but also of Yaʿqūbī (around 276/889–90).

The other reason, more difficult to explain, from the birth of the project of description of the *mamlakat al-Islām* keeps perhaps to the *adab*, always to it. It has been said above that it used any means it could, the only rule being that of an accessible knowledge, common as we would say today. Why not think then that the Muslim domain – just the known only, in the system of the *adab*, in the form of some odds and ends: famous products or curiosities, some monuments for example – could be also, but en bloc this time, integrated into the knowledge of the honest man? It is very much in this way that al-Muqaddasī, at least, understood it. When he tells us of fine work to do, when he joins, to the array of possible readers of his book, the cultivated élite, when he tries his hand finally, here and there, at rhyming prose and even, in conclusion, at poetry, what else is he doing if not showing that he wants to indicate, in spirit and in letter, a work made also for non-specialists, curious about everything and attentive to this 'literization' of all the themes possible which, as Grünebaum had most definitely seen, is the supreme mark of the cultural system of the time?

The spirit in which this new geography is conceived belongs at the same time to heritage and to innovation. Heritage, this is the books, criticized perhaps, but cited. There is nothing to be gained by genre being created, knowledge being born, if one does not first call upon patrons. But this tribute paid and the game being played according to the established rules, innovation can intervene. It resides in direct observation, the thing seen on the spot and recorded in a real-life situation, all things happening on the journey. The peregrination continues, throughout Islam or almost, becoming the first foundation of knowledge. Let us measure the path accomplished. With very rare exceptions, such as Abū Dulaf Misʿar for example, author of two accounts (*risāla*), one, somewhat suspect, on Central Asia, Malaysia and India and the other, highly remarkable in contrast, on the countries of Iran and Armenia (about the middle of the fourth/tenth century), everything occurred as if there was the choice of two attitudes: to recount, one has said, one's journey, but abroad, or to travel inside Islam – on business, for the State, for a pilgrimage to Mecca, to go and receive or dispatch some information – but without saying it, at least without making the voyage the object of and the reason for a book. Everything now changed, as if the Muslim world where one was living, in which one was living, was yet to be discovered.

A subject, a spirit, a technique finally. Of all that illustrates the geography of Islam, in this second half of the fourth/tenth century, the most conscious of the innovation was without doubt al-Muqaddasī. He first built up, or rather set up himself, a vocabulary. The words of the current language, referring to differing degrees of quality, thus become as many labels to display the value of products. But in particular one allocates to the countries and their towns some specific terms which define their hierarchy. At the top, the province, *iqlīm*, the old reproduction of the Greek *klima*, taken here, sign of the times, in a new sense. At the head of the province, the metropolis (*miṣr*). Below, the districts (*kūra*), with their chief town (*qaṣaba*) and their estates (*madīna*), this last term implying the presence of a large mosque with its *minbar*, visible mark of the presence of power since it is from here, every Friday, at prayers, that the invocation to the prince who built up the town is made. Apart from these, two territorial divisions, the region (*nāḥiya*) and the canton (*rustāq*), the first too small to be set up as an *iqlīm* but too large to be put on the same level as a *kūra*, the second including several localities but not enough to constitute a *kūra* on its own.

The construction of the work took place with the same desire for thoroughness. Each province was the object of a brief general presentation, then of a description *kūra* by *kūra*, then of a global study, by large rubrics: climate, water, produce, weights and measures, money, trade, taxes, customs, juridical and theological schools, sacred places, power in place, itineraries. But what, all things considered, is a province? Quantitatively speaking, one of the fourteen subdivisions of the Islam world, six Arabic and eight non-Arabic (from Armenia to the Indus by passing through the Iranian countries), notwithstanding marked variations in size. More important: from the Greek 'climate', skilful construction, one has passed to a new meaning for *iqlīm*: each of these subdivisions of the Muslim world appeared very much as a country, a real individualized country through geography and history, the latter coming to confirm the former in the form of an independent power, at one or another stage in the past of the province, and until this fourth/tenth century sometimes.

Beyond, at the top, the *mamlakat al-Islām*, so strongly perceived that the expression here and there is found reduced to one of two terms: the Domain (*al-mamlaka*), Islam. An indicator, one sees, of the powerful conscience of a unit being divergences and differences: political divergences between the three rival caliphates of Cordoba, Baghdad and Cairo, infinite differences in climate, the relief, the uses, the languages, the metrological or monetary systems. Despite the divided empire, one has to speak of an imperial geography, reflection of an immense ensemble, a composite with many sides, nevertheless united and conscious of existence across Islam and the multiple forms of everyday life, collective or private, that inspire it. Geography at the top, ephemeral geography. The year 400 which awaits it, the year 1000 of our time, is going to turn the countryside upside down.

The major phenomenon is here the arrival in force of the Turks of Central Asia, their hand placed on the caliphate of Baghdad, prelude to its disappearance under the Mongol shock in 1258, the Arabs dispossessed for a long time from historical initiative. Let us also put on the scene the enterprises of the Christian West, *Reconquista* in Spain, Crusades elsewhere, the expansion of Sunnism, the more and more charged break between the West and the East of Islam. For geography, the effects of this new situation will be of three orders. One will witness first the rupture with the recent past, i.e. with the forms taken by geography in the second half of the fourth/tenth century. At the same time, one will return sometimes to the earlier forms, perhaps through a desire to refind the models of eras considered more safe, happier, and to break away from those which one estimates to be too tied to a recent historical failure. At last, and fortunately, one will create: this will be the rapid development of tendencies directly issuing from the new conditions that history imposes on the Near East after the year 1000. The crisis, in every case, is prolific: it opens onto an abundant production and some of the greatest names in geographical science. Let us see how this occurs and what must be understood, after the year 1000, by geography.

But first, the breaks. The first concerns the area assigned to geography. At the very time when Arab geography realized its greatest accomplishment around the idea of *mamlaka*, the reality that it wanted to transcribe was already faltering, before disappearing. Even divided, the Arabo-Muslim world remained one, not only, it has been said, through its belonging to one and the same civilization, but also through the aim that founded it: Umayyad in Cordoba, Shiʿite in Cairo, Abbasid in Baghdad, a caliphate was always involved, in other words a power who recalled that the Muslim community had a calling, against all comers, to unity. Now, the eleventh century saw the caliphate of Cordoba disappear in 1031, then, as has been seen, that of Baghdad passed under the Turkish yoke (1058) and sank into Mongol torment (1258), and that of Cairo finally declined before also perishing (1171). The only true burst of a caliphian idea: the Almohad dynasty, but it did not pass beyond the west of Islam and lasted for little time (1147–1269). In a world so disrupted, which saw Islam disappear bit by bit at a time of communal political construction for the ensemble of the faithful, is it any wonder that the very concept and expression of *mamlakat al-Islām* disappeared, once and for all, from all our texts? Worse: the geographical school from al-Balkhī to al-Muqaddasī which has attached its name to this 'atlas of Islam', as one sometimes calls it, has not survived, even as a memory; the only book that one could still associate with this tradition, more or less arbitrarily, the *Kitāb al-masālik wa-l-mamālik* (*The Roads and the Kingdoms*), by al-Bakrī (d. 1094), is organized not by province but by itinerary, and without invoking, whatever the circumstances, the name or concept of *mamlaka*. A page is decidedly turned, and one would nowadays talk about a geography of regions, of countries, of States, or even of the whole earth, indeed the universe.

Another break which touched the area of expression. Before the year 1000, geography participated in a large cultural movement that had inspired the best of the Abbasid civilization: an Islam gatherer of ethnic groups, under the double banner of Islam and of Arabic as the language of exchanges, whatever they were, had started with those of knowledge. Thus a good number of authors who had added lustre to the geography with Arabic expression were Iranians by origin, with one or two exceptions. After the year 1000, the Turkish invasion, then the Mongol, disrupts the linguistic map of the Orient, in three ways. First, there was the disappearance of the centres of Arabic culture which, from beyond Mesopotamia and up to Central Asia, had given literature in this language some of its greatest authors. At the same time, the second change becomes apparent: Iraq becomes the frontier of the Arab world and its language, both definitively installed in the domain which is theirs today. Finally, owing to the Turkish invasion, some nations, culturally speaking at least, appear or reappear on the new scene of the Orient: the Turks justly, initiators of this history, and the Iranians whose culture reveals itself to be decidedly ineradicable and survived all these interruptions. Some others will express themselves more in their language, at least for all that does not involve religion and the sciences. Geography will therefore follow the movement; on occasions it will be Turkish or Persian, and Arabic held back, confined to its own linguistic area, will lose there at the same time the exclusivity of geographical expression.

Third and final break: concerning the places of production of geography. Before the year 1000, it is the East which dominates, and Baghdad more particularly, Baghdad that every cultured man must visit, or cite at the very least. The town and the country of Iraq, even in full decline as is already the case in the fourth/tenth century, continue to be held as the centre of knowledge, the pole of culture, for its styles and its code. As far as Spain, even the Spain of the caliphate of Cordoba, the literary norms, the good taste, the knowledge are the same as those that Baghdad decrees or inspires. Geography, once again, went with the flow. Written by Orientals, it gave a place of choice to the description of Iraq and its capital, underlined their vicissitudes without doubt, but continued to see the world through them, and from them: the essential, the best, the most searching of the description attaches, with Iraq, to the countries towards which, quite naturally, Baghdad looked: Egypt, above all Syria and Arabia on one side, Armenia and the Iranian domain on the other. After the year 1000 in contrast, the Maghrib, which Ibn Ḥawqal defined as 'the sleeve of a garment' of which the body, of course, was the East of Islam, makes a sensational entrance into geographical literature. Not only the data will be better defined and more developed, but the centres of production of Arabic geography will be situated not only in the East, but in Sicily and North Africa, both illustrated by very great names.

The new context which was created after the year 1000, in the furore of invasions, is clearly one of great confusion. This without doubt largely explains the movement of the ensemble of Arab scholars of the time. One turns then less towards creation – poetry will bear the cost – than towards recording, compilation. All with an inexhaustible ardour, as if one wanted to save the heritage, in all areas, or, who knows? To testify one day, to the whole world, that the Arabo-Muslim civilization, perhaps mortal or at least precarious, uncertain as all the others – this is one of the central themes of the remarks by the great historian Ibn Khaldūn (1332–1406) – had at least lived, and produced fantastically. It is in this climate of unity, of withdrawal into oneself at the same time as exalting patrimony, that geography, or at least a certain geography, will be established with the other disciplines. The majority of the forms assumed before the second half of the fourth/tenth century will thus be revived, with the notable and already indicated exception of the 'atlas of Islam'. Why was the tradition not kept, conversely to the other forms of geography? One can only note that history, which created this genre and this discipline, almost immediately took away from it the very conditions and materials of its survival. For the rest, the mystery remains, unless one proposes that the geography of the years 950–1000, founded on a *mamlaka* which was proceeding already from a dream or from a great recollection more than from reality, had pushed the concept so far that, once crumbled under the blows of history, its artificial upholding was only able to produce too much of a verisimilitude and perhaps also too much distress.

First reappearance: that of the encyclopedia. The word, here as elsewhere, can branch into two meanings: desire for total knowledge on the grounds of universal discovery, as in the century of the Enlightenment, or recording of a complete knowledge, here again, but considered to be fundamentally and even definitively acquired. It is agreed, with reference made to the context evoked, that under this second form is presented, essentially, Arabic encyclopedism from the year 1000. Two treatments of the information are possible: one can either build a unique citadel of total knowledge by including in its surroundings, among other things, geographical knowledge, or realize the global enterprise in the form of many specialized citadels. One or the other process will, effectively, be followed.

The first goes back to a tradition already known to us, that of the officials or the 'honest man', Ibn Khurdādhbih or Qudāma on the one hand, Ibn Rusteh or Masʿūdī on the other. But the notable fact is that after the year 1000 the two movements are now only one. Here, it is Egypt, the Egypt of the Mamluks, that leads the game, by virtue no doubt of the permanence of the old Baghdadian models: just as the Mamluks welcomed and symbolically proclaimed Caliph an Abbasid who escaped from the massacre of his family by the Mongols in 1258, so they wanted to draw inspiration from the administrative usages of Iraq for the education of officials and the practice of their task. The scribe will therefore be, as before, a qualified technician, a stylist of honest quality and a cultured man, better still a man so cultured that he can be no other. Instead of lighting up, more or less, in the beacon of the *adab*, it is him now who will be the headlight, of this *adab*. Thus, his function will at first open on the disciplines necessary to the specialist, religion, law, tradition, and then step by step on the others: literature, which offers him models of style; history, which will inform about local situations; finally geography, for a double usage – information on the resources or the customs of the countries administered, and the description of the terrestrial globe and foreign peoples, which with those taken here and there from other disciplines will form some of the themes of this general culture without which there is no good, no true official. Mamluk encyclopedism thus reunites the true traditions that preceded it, and takes the genre to its summit. The personage of the official scribe gathers definitively to him those of the technician of practical administration and the cultured man; he integrates this practical experience into the most vast knowledge possible. Geography, with the double usage just mentioned, takes part in the construction of the whole and is no less necessary to it than the rest of the disciplines. Of this construction, of this ambitious citadel, one follows the steady development through three major works: the *Nihāyat al-Arab* of al-Nuwayrī (1279–1332), the *Masālik al-abṣār* of Ibn Faḍl Allāh al-ʿUmarī (1301–49) and the monumental *Ṣubḥ al-aʿshā* of al-Qalqashandī (1355–1418).

Encyclopedism can also be carried out, as has been said, by collecting knowledge in one or another domain. For geography, the enterprise aims at first to fix the place of the earth within the universe, in other words to construct a universal geography. Such was the aim of the Arab successors of Ptolemy and Indian astronomy. After the year 1000, this fine effort of discovery and bringing up to date only survived in moments, in jumps as with Ulugh Beg (d. 1449), great prince protector of scholars and a great mathematician. Yet these astronomical tables (*zīj*) were produced in Persian. Thus some jumps, and then nothing.

There is nevertheless another more practical way: that where all who want can involve themselves, in a simple and accessible form, in supplying the results of research by the scholars to a cultured but non-specialized public: the *adab*, always. . . . Here it will concern in particular the presentation of the earth: astronomy, to fix its place in the universe, but also astrology, to explain the effects here on earth of the heavenly bodies, cosmology and cosmogony, all reduced to a few easily assimilated themes and whose prime function will be to introduce the main point of the work: the description itself of our globe. This will comment on the mountains, the seas, the rivers and the living beings. A real effort to collect information, an effort which nevertheless must not hide from us the limits and gaps of the enterprise: it no longer survives on steadily conducted research, and the spirit which animates it too often lets pass the lucidity, the objectivity, for a taste altogether too hidebound for curiosities and even marvels, the *mirabilia* (*ʿajāʾib*): the theme and the word are constant, and this from their title, in the encyclopedias of Abū Ḥāmid al-Gharnāṭī (d. 1169–70), al-Qazwīnī (1283), al-Dimashqī (1327) or Ibn al-Wardī (1457).

Another form of encyclopedism: dictionaries. New form, in truth, for a tendency which was only found in germ before the year 1000, through one or another monograph of country or town included in more general works, those of Ibn al-Faqīh for example. Two names to remember here: al-Bakrī, already mentioned, and Yāqūt, who died in 1229. The first delivers us a dictionary which, as such, brings out rather more about linguistics than about geography: it comprises lists of toponyms interesting to the first leader of Arabia, accompanied by a general presentation of the country. Yāqūt, in his case, goes infinitely further with his *Dictionary of Countries* (*Muʿjam al-buldān*). For countries, regions or towns, presented in alphabetical order, the author offers us not only philological information on these toponymes and some texts where they are cited, but above all precise details about their exact location, productions, monuments and other curiosities, the great personages originating from the area or who lived there. The merits of this book are immense. It invites us on a veritable tour of the Muslim or foreign world, presented in an easy form without polish, immediately available for research that could solicit it at any instant. Elsewhere, Yāqūt collects a mass of data supplied by previous, sometimes lost, works. The last merit finally: the *Muʿjam* resumes brilliantly that which Ibn al-Faqīh called the science of countries: total knowledge, which intends, with regard to one or another toponym, to collect all the information that can be related to this name, lexicographical, historical, geographical, economic, religious. . . . Immense in its aim, infinitely more than any other geographical work before the year 1000, rigorous in its method, critical when necessary, the dictionary by Yāqūt remains to the present an indispensable and regularly consulted book.

It is not only the encyclopedia that recovered its name after the year 1000. The *ṣūrat al-arḍ*, also, was reborn from its ashes. Incontestably, it is the disappearance of the concept of the *mamlaka* which revived the idea of a precise geography, climate by climate (in the old sense of the word) of the whole earth. The major works are here those by al-Zuhrī (about 1137), al-Idrīsī (d. 1166), Ibn Saʿīd (1274) and Abū al-Fidā' (1331). First remark: only one of the four, Abū al-Fidā', is an Oriental, Syrian more precisely. The others come from the West, or worked there: al-Zuhrī and Ibn Saʿīd are Spanish, and al-Idrīsī becomes famous in the Norman Court of Roger II of Sicily, for whom he will erect his famous silver planisphere. Thus the text and map of the *ṣūra* make a good place for some data, new or corrected, relating to the West, and notably to Europe which, before al-Idrīsī, hardly came out of the shadows.

Another observation; just as it recorded the progress of the knowledge of the earth, this *ṣūrat al-arḍ* made its own also some of the lessons of geography from the years 950–1000. Not, obviously, through the concept of or the word *mamlaka* – both disappeared – but through a precise practice of the description of countries, non-existent (or almost) in the *ṣūra* before the year 1000 and of which the 'atlas of Islam' made one of the foundations. Thus the new *ṣūra* will cause the intersection of two schemes of organization, one by climate and the other by country, and two types of presentation, one by geographical coordinates and the other by descriptive pictures. For this double process, it is Abū al-Fidā' who will be the best and almost exemplary representative. It remains that the new forms of this geography after all ambiguity reflect perfectly the disruption that intervened in the history and conscience. These countries that are presented to us through the grid of climates, these are the countries of the whole world. Even if those of Islam take up the best part, they are no longer alone, as in the 'atlas', in constituting the universe of men or at least its best part, and above all they no longer constitute a sole and unique group under a sole and unique name.

Is it necessary to evoke local geography, as a last aspect of the possible resurgences? We have not spoken about it before the year 1000, and for a good reason. Except for, at the turn of the century, the famous, masterly and exceptional work of al-Bīrūnī (973–1048) on India, which attempts to cover all possible fields of knowledge about this country, the texts in question are mostly about history, which led the game; the few passages relating to a description of places or to productions took place in works designed to exalt local patriotism in the light of a past the evocation of which, it should be emphasized, constituted the increasing majority of the enterprise. Very much linked to principalities or local patronage, this literature only really flourished after the year 1000, and in Persian for the countries beyond Mesopotamia. Arabic integrated itself willingly into the general works, such as the encyclopedias, already mentioned, of Mamluk Egypt. In every case, in this form or in the form of a monograph, it will be brought out, in order to reorganize the merits of the different countries or towns, to deepen as much as to multiply the investigations: so many sources often irreplaceable for our knowledge of the Arabic Orient after the year 1000.

It remains to mention, to finish, some new aspects of geography starting from the eleventh century. New, yes, because if one could find some antecedents, prefigurations, before this date, as we have done for Yāqūt for example, the changes that occurred would be looked upon, here, as revolution. First religious geography. Without doubt it existed previously, by the mention, concerning one or another place, of the memory of a biblical character, of a companion of a prophet, of a holy man. But it was a case of fragmented, brief pieces of information, integrated into other works. From the eleventh century onwards, however everything changes. The expansion of Sunnism, its concern to unite Islam against outside danger, that of the Crusades in particular, and finally the expansion of a popular concerned commitment to finding, apart from distant Mecca, places of remembrance and prayer, impel not only to continue to indicate these by way of descriptions of countries or towns but, again and above all, to write proper specialized guides, the model for which is realized by the *Kitāb al-ẓiyārāt* of al-Harawī (d. 1214). *Ziyārāt* signifies 'visits', pious in this case: to holy places, to the tombs of great men of Islam, to the monasteries of the mystics, to the schools where doctrine was taught. Geography? Yes without doubt, because some of the themes which form the 'science of countries' with which we are already familiar reappear on the scene: distances and itineraries, typonymic and topographical notation, and even sometimes descriptions, albeit brief. But geography, also, because these books invite us to imagine the territorial ensemble which provides the basis of the description. Divided into countries, as with an Ibn al-Faqīh or an Ibn Ḥawqal, this ensemble nevertheless goes beyond them; what is communicated to us in this way is the world of Islam, from its old 'atlas', but clearly grasped from a different angle: beyond a specialized evocation, religious in this case, is read a testimony, the sign of a desire to survive, to keep intact the conscience of the reality of a Muslim entity, though politically shattered.

Change again with maritime literature. This was also known before the year 1000, in the form of books by seafaring man, such as the *Account of China and India*, but also, for the seas surrounding Arabia, in records relating to coastal navigation, to winds, ports, buoys and dangerous passes; such records do not, themselves, constitute separate works but are integrated into descriptions of countries, notably in the 'atlas of Islam' as can be seen in the work of al-Muqaddasī. With the eleventh century, all this was moved aside for the benefit of a proper geography of the sea, at least from the Eastern side.

For the Atlantic in effect, it is the old form of the story of a voyage which remains, at least as far as can be ascertained from the extracts that al-Idrīsī, taken up again by Abu Ḥāmid al-Gharnāṭī and Ibn Faḍl Allāh al-ʿUmarī, has kept for us of the recollection of eight young people who set out for Lisbon and who would have visited, in the tenth century, the waters of Madeira and the Canary Islands; extracts, also, that Ibn Saʿīd relates of an Ibn Fāṭima who would have explored, towards the middle of the thirteenth century, the shores of Western Africa up to the White Cape. On the side of the Mediterranean, after the year 1000 things remained in the same state; it is a disputed sea, militarily and commercially, badly controlled, not well known, in the north particularly; the new information offered by al-Idrīsī does not prevent the Mediterranean being seized by its shores or its islands. Nothing, in any case, of a true literature of the sea; it is necessary to wait for the Ottomans.

It is in the East that the change occurs. Before the year 1000, in addition to the texts mentioned for the seas of the Far East or Arabia, it is necessary to indicate also the maps and portulans, known from the end of the ninth century but which came to experience their real expansion in the fifteenth and sixteenth centuries. Is one justified, in these conditions, in talking of change? Yes nevertheless, if one considers two facts. On one hand, what is known about the maps and portulans from before the year 1000 comes down to a few rare names, and not one work has reached us. But above all, it is necessary to take into account, in the new history created by the great discoveries, the size and quality of the information supplied, which make them very much a feature of innovation. On the routes of the Indian Ocean, two names: Sulaymān al-Mahrī, who wrote at the beginning of the sixteenth century, and above all his elder, Ibn Mājid, the pilot of Vasco da Gama, whom he guided, in 1498, from East Africa to India. An unrelenting sailor was the former, since he spent fifty years of his life on boats, but author also: more than thirty or so nautical treatises. With Sulaymān and him, the Arabic science of navigation, of the ocean and of the stars reaches its peak. But it is true that it is to die. Following the new history of the world which is going to belong henceforth, on these seas of Africa and the Far East, to Europe, Arabic science of the sea is also going to give way to those who become masters on the waters: through arms and the knowledge, the people of the West.

The great innovation after the year 1000 is, all things considered, the journey log book (*riḥla*): journal, and not only an account. It is based in effect on a new form of literature which consists of noting one's impressions from day to day, by making a time, a place and an individual adventure run in parallel. At the start, it is a journey to the holy places of Islam and to the reputed sources of knowledge found always, at least for the best among them, in the East. Whence the entrance in force of the Maghrebians in this literature, to the intersection of the pure voyage and the research of teachers, of the *riḥla* and the *fahrasa*: thus it goes, in the thirteenth–fourteenth centuries, from al-Nubātī, al-ʿAbdarī, al-Ṭayyibī and al-Tījānī and, in the seventeenth century, al-ʿAyyāshī. Of all of them, yet, the greatest are Ibn Jubayr and above all Ibn Baṭṭūṭa. The first (d. 1217) gave to the *riḥla* its journal form; the second made an even more considerable step, by transforming the pretext journey into simply a journey.

By the very size of the journey, first. Let us judge rather: leaving from Tangiers, his birthplace, at the age of 21, in 1325, Ibn Baṭṭūṭa only saw it again twenty-four years later, at the end of a journey of some one hundred and twenty thousand kilometres which would have led him to countries as varied as the Arabic world, Spain included, Central Asia, Constantinople, South Russia, Anatolia, Iran, India and the Maldive Islands, Ceylon, Bengal, Sumatra, the ports of China, Eastern and sub-Saharan Africa. A formidable innovation in itself, already, this raw material of the *riḥla*. But this journey was not only the chance to record unrivalled data, it formed also the surroundings where Ibn Baṭṭūṭa quite naturally inserted his life, married here, divorced there, elsewhere judge, trader, ambassador, advisor of princes. Impressive also, this *riḥla*, because it talks resolutely about modern times. Created in the context after the Mongols, in a politically shattered Islam, it is placed opposite to the vision of the *mamlaka* which was that of the 'atlas' from the years 950–1000. But it does not run after the missing dream and, taking the world as it is, substitutes for the old *mamlaka* another, more sure, infinitely more lively, and lasting to the present: that which, Arabic or not, stretches from one end of the earth to the other and whose unity continues to be based on Islam, on the customs and life that inspired it: one same 'family', as Ibn Baṭṭūṭa puts it. With him, who closes the great history of Arabic geography, opens the geography of the present times.

# 24

# *Botany and agriculture*

TOUFIC FAHD

In classification of the sciences, it was a long time before botany and agriculture were considered as two distinct disciplines. The first work on agriculture, *Nabatean Agriculture*, is also a work on botany. Agriculture and botany are sometimes classed amongst the medical sciences, in view of the importance of plants in the treatments of illnesses. Nourishment and therapeutics were at the origin of botany and agriculture. The care of the agriculturist is to feed men, that of the botanist is to heal them – whence the double meaning of the title *filāḥa* on the most ancient treatises. It means both care for the earth and the care of plants.[1]

The Arab lexicographs separated the two disciplines very early, dedicating monographs to plants, but the authors of agricultural treatises could only filter the data about the nourishing qualities and medical properties abundantly given by the first geoponic texts. Apart from its agronomic content, the *Nabatean Agriculture*, which is the model of its type and the source for all later authors, provides information for a cook book and a treatise about simples. A long theoretical exposition about the genesis and causes of plants can also be found there along the lines of the treatises of Aristotle and Theophrastos.[2]

Botany has progressively detached itself from agriculture under the influence of two Greek sources, translated into Arabic and becoming the starting point of Arabic botanical science, i.e. the *Causes of the Plants* of Theophrastos (*c*. 372–287) Aristotle's disciple, of which the Arabic translation is lost, and the *Materia Medica* of Dioscorides, an Eastern author of the first century of our era.

We need to recognize, however, that with al-Dīnawarī, who wrote at the same time that these texts were being translated, Arabic botany acquired its autonomy as part of the sciences of the language, a normal outcome of all the research undertaken by the Arab philologists since the beginning of the third/ninth century. It is thus at least that the work of al-Dīnawarī is presented, reaching us without its beginning, reconstructed in part from the great Arabic dictionaries. With the *Nabatean Agriculture* it constitutes a base for the study of Arabic botany.

## ARABIC BOTANY

The limits of this chapter do not allow us to make an exhaustive study of Arabic botany. This could be the subject of a book in itself. We shall limit ourselves here to giving a glimpse of the sources, a classification of plants and a summary of their phytobiology and morphology.

### I The sources

#### *1 The lexicographic sources*

The interest of the Arabs for lexicography goes back to the middle of the second/eighth century; the first names mentioned in this area are ʿĪsā b. ʿUmar al-Thaqafī (d. 149/766), Khalīl b. Aḥmad al-Farāhīdī (d. 160/776), Sībawayh (d. 161 or 177/776–7 or 793), al-Kisāʾī (d. 207/822). Those who have collected botanical lexicons are as follows:

- Abū Zayd al-Kilābī (d. 204/820) in *Kitāb al-nawādir*; he divides vegetable matter into *shajar* (trees), *ʿiḍāh* (thorny trees), *ʿushb* (herbs), *aghlāth* (bitter plants), *aḥrār* (vegetables that can be eaten raw), *dhukūr* (vegetables with a slightly bitter taste), etc.
- Al-Aṣmaʿī (d. 216/831) in *Kitāb al-nabāt wa-l-shajar* (*Plants and Trees*); he gave the names of 276 plants of which many are collective designations, such as *rabl* (plants which get green again at the end of Autumn without rain, following cold nights), *ribba* (trees constantly green like the carob tree). He divides the vegetables in *aḥrār*, *dhukūr* and *ḥamḍ* (salsigineus and bitter plants), *ʿiḍāh*. He names the plants which grow in different regions of Arabia (the Ḥijāz, the Najd, the Sarāt, the deserts).[3]
- Abū Zayd al-Anṣārī (d. 214/829) under the same title gives a complete table of the plants in Arabia, adopting the same divisions as his predecessors.[4]
- Ibn al-Sikkīt, teacher of Abū Ḥanīfa al-Dīnawarī wrote under the same title a work mentioned more than 200 times in the *al-Mukhaṣṣaṣ* of Ibn Sīda.
- Numerous authors are attributed a *Kitāb al-nabāt wa-l-shajar* but the texts are only known to us through quotations made by al-Dīnawarī. He has used his predecessors extensively in the composition of his *Kitāb al-nabāt*.

- Abū Ḥanīfa al-Dīnawarī (d. *c.* 282/895) was the founder of the Arabic botany. It was Silberberg who had the merit of making the work of this great botanist known in a thesis defended in Breslau in 1908 with the title *Das Planzenbuch des Abū Ḥanīfa Aḥmed ibn Dā'ūd al-Dīnawarī. Ein Beitrag zur Geschichte der Botanik bei den Arabern.*[5]

According to ʿAbd al-Qādir al-Baghdādī,[6] the *Kitāb al-nabāt* of al-Dīnawarī comprised 'six big volumes', of which only the third[7] and the fifth[8] have reached us. Muḥammad Ḥamīdullāh reconstructed the sixth volume from citations he picked up in the big dictionaries and in numerous monographs. He collected descriptions of 637 plants going from letter *sīn* to letter *yā'*, completing thus the part of the alphabetic dictionary published by Lewin which goes from letter *alif* to letter *zayn*. We thus have a complete lexicon of this great treatise on Arabic botany.[9]

As for the contents of the *Book of Plants* from al-Dīnawarī as it was reconstructed by Silberberg and Ḥamīdullāh, we can summarize it as follows: after a first part of astronomical and meteorological character describing the sky, the constellations, the planets, particularly the sun and the moon, the lunar houses indicating seasons and rain, al-Dīnawarī dedicates a long exposition to the *anwā'* (the heavenly bodies of rain) and atmospheric phenomena (winds, thunder, lightning, snow, floods, valleys, rivers, lakes, wells and other sources of water). Then he considers the earth, stones and sand, describing different kinds of ground, indicating which is convenient or not for plants. He describes the qualities and the properties of good ground.

After this long introduction of which we can find a model in agricultural treatises, he undertakes a description of plant evolution from its birth to its death, going through the phases of growing and production of flowers and fruit. He then goes on to cereals, vineyards and wine, date palms and dates. A long explanation where he draws information from his predecessors is dedicated to trees of the mountains, the plains and the deserts, aromatic plants, plants used in dyes, plants used to make toothpicks, wood for kindling, the ashes and the smoke and their colours according to the different woods, honey and bees, the wood which is used for the fabrication of bows and arrows etc.

According to Ḥamīdullāh, al-Dīnawarī's treatise should include two parts of different length: the first dedicated to botany and occupying four and a quarter volumes, the second consisting of an alphabetic dictionary briefly describing plants in one and three-quarter volumes.

Al-Dīnawarī dedicates one chapter to the classification of plants (*tajnīs al-nabāt*); he mentions it five times in volume V, published by Lewin. In the absence of this chapter it is difficult for us to know what the classification was. We do find, however, the classification of his predecessors for trees, herbs, vegetables that can be eaten raw, slightly bitter vegetables, salty and acid plants, bitter plants, creeping plants, thorny bushes, mountain trees, desert plants. This classification was common with his predecessors, particularly al-Aṣmaʿī.

The contribution of al-Dīnawarī to botanical science is fundamental. Silberberg underlines its importance and originality in very flattering pages summarized by Fuat Sezgin (1970: III, pp. 338–43). He was the source used by the authors of the great dictionaries such as *Lisān al-ʿArab* and *Tāj al-ʿArūs* and the great lexicons like the *al-Mukhaṣṣaṣ* and *al-Muḥkam* by Ibn Sīda, as well as by the authors of treatises about medicinal and nourishing plants, such as Ibn al-Bayṭār in his *Jāmiʿ li-mufradāt al-adwiya wa-l-aghdhiya*.

## *2 Agronomical sources*

This abundant botanical terminology comes with elements which allow us to glimpse the beginning of a systematic taxonomy, of a structural morphology, of an ecology, of a phytosociology, of a biogeography, elements which we find again in the agronomical and botanical sources. These sources are in a first phase essentially in Greek, Syriac or Pahlavi languages. They were translated into Arabic during the eighth and ninth centuries of the Christian era.

Among the ancient geoponic sources, the Arabs knew the *Georgika* attributed to Democritus, identified by Wellmann with Bolos of Mendes, an author of the second century before our era.[10] Fragments still exist in Arabic manuscript 2802 in the Bibliothèque Nationale of Paris, in a Byzantine manuscript from the seventh–eighth century[11] and in a Syriac manuscript in the British Museum, dating probably from the ninth century.[12] It is frequently quoted by the Arab agronomists, particularly those from Andalusia.

They also knew the *Synagogé* of Vindanios Anatolios of Berytos, an author from the fourth–fifth century of our era, translated into Arabic with the title *Kitāb al-filāḥa* and from which, according to Sezgin, an Arabic manuscript exists in Mashhed.[13] It is a large compilation which is only partly known;[14] it is frequently mentioned by Arab agronomists either under the name of Anatolios or, according to Ullmann, under that of Junius.[15]

The third geoponic compilation well known to the Arabs is the *Georgika* of Kassianos Bassos Scholasticos, an author from the sixth century of our era, mentioned under the name of Qusṭūs or Kassianos. It was translated into Arabic with the title *al-Filāḥa al-rūmiyya* by Sarjīs b. Hiliya al-Rūmī around 212/827, directly from the Greek; another translation was made indirectly from Pahlavi[16] under the title *Kitāb al-zarʿ*, a title that one finds amongst authors such as al-Naḍr b. Shumayl (d. 203/818), Abū ʿUbayda Maʿmar b. al-Muthannā (d. 207/822), Abū Ḥātim al-Sijistānī (d. 250/864) and others. The two versions are mentioned by Arab agronomists and are well represented in collections of Arabic manuscripts. The direct version was published in Cairo in 1293/1876.[17]

But the most important of these translated sources is the *Nabatean Agriculture*, a monumental book translated from Syriac at the end of the eighth century of the Christian era.[18] The study of plants occupies more than half. In the absence of the systematic part from the *Kitāb al-nabāt* from al-Dīnawarī, the *Nabatean Agriculture* remains the most eloquent testimony to the richness of Arabic botany. We shall adopt this classification.

### *3 Botanical and pharmacological sources*

The most important of these sources are as follows.

The *Treatise of Plants* attributed to Aristotle and commentated by Nicholas of Damascus, in the first century before our era, was translated into Arabic by Thābit b. Qurra (d. 288/901) and revised by Isḥāq b. Ḥunayn (d. 298/910). It is used by Arab authors for the physiology of plants. The Greek original is lost; the Arabic version was translated into Latin under the title *Liber de plantis*. The Arabic text was published in Cairo in 1954 by ʿAbdurraḥmān Badawī.[19]

The *Causes of Plants* by Theophrastos was translated, partly or wholly, according to Ibn al-Nadīm (*Fihrist*, 252), during the second half of the third/ninth century, by Ibrāhīm b. Bakḳūsh, a physician from Baghdad, under the title *Asbāb al-nabāt* (*Causes of Plants*), a translation which has yet to be found. A large section of the *Nabatean Agriculture*, dedicated to the physiology and morphology of plants, calls to mind in several aspects the contents of the book of Theophrastos. The same goes for the fourth section of the work attributed to Apollonius of Tyana entitled *Sirr al-khalīqa*[20] and a chapter of the *Book of Treasures* by Job of Edessa.[21]

The *Materia Medica* by Dioscorides, an author from the first century of our era, born at ʿAyn Zarb in Cilicia, devotes an important part to botany, dividing the plants into aromatic, nourishing, medical and poisonous. It also considers the origin of plants, their physiology and their evolution. It was translated into Arabic and commentated several times. The first translation goes back to the time of al-Mutawakkil (233–247/847–861).[22]

It is important to mention here that the development of Arabic botany is due to a great extent to medical and pharmaceutical research. A *Risāla fī al-ṭibb wa-l-filāḥa* (*Epistle on Medicine and Agriculture*), still not edited,[23] is attributed to Caliph al-Ma'mūn (d. 218/833). ʿAlī b. Sahl Rabbān al-Ṭabarī (d. *c.* 240/855), author of an encyclopedic work on philosophy, physiology, psychology, hygiene, medicine, pharmacology, climatology, cosmography, astronomy, etc. entitled *Firdaws al-ḥikma* (*The Paradise of Wisdom*), gives an important place to botany. Werner Schmuker extracted from this encyclopedia the 'medical and mineral matter' that it contains.[24]

Ibn Sīnā (980/1037) dedicates a long exposition to the physiology of plants in his *ṭabīʿiyyāt* (*physica*) which constitutes the seventh section (*fann*) of his *Kitāb al-shifā'*.[25] It concerns the constitution of plants, their organs, their nourishment, the differences between them, the functions of the roots, of the branches, of the leaves, of the fruits, of the seeds, of the thorns, of the gums, the wild and domestic plants, etc. Botanical considerations of Ibn Sīnā show rather a philosophical aspect; the accent is on causality and finality. The influence of *Liber de plantis*, attributed to Aristotle, is noticeable.

The same influence is found with Ibn Bājja (Avempace, d. 533/1138), the famous author of a pharmacological work entitled *Kitāb al-tajribatayn* (*Book of Two Experiences*). He dedicates to the physiology of plants a *Kitāb al-nabāt* (*Liber de plantis*) where he emphasizes their infinite variety; he divides them into perfect and imperfect, the latter being those lacking the main organs; he writes on their sex. In summary, this is a disorganized exposition, like the Pseudo-Aristotelian text which inspires it.[26]

Ibn al-Jazzār (d. 369/979) wrote a work on medicinal plants which was very popular in the Middle Ages and was translated into Latin, Greek and Hebrew.[27]

Ibn Samjūn (d. 392/1002) collected in a kind of medical encyclopedia the knowledge of Arab physicians on the utilization of medicinal plants or simples. His work entitled *Jāmiʿ al-adwiya al-mufrada* (*Collection of Simples*) is made up essentially of quotations from his numerous predecessors who studied medicinal plants, from Dioscorides to Ibn al-Kattānī, going through Galen, Oribasius, Paul of Aegina, Pseudo-Aristotle, al-Dīnawarī, Ibn Waḥshiyya, Rabbān al-Ṭabarī, Yaḥyā b. Māsawayh, Isḥāq b. ʿImrān, Yūḥannā b. Sarābiyūn (Serapion), al-Isrā'īlī, al-Rāzī and others.[28]

Abū al-Qāsim al-Zahrāwī (the Abulcasis or Albucasis of the Latins, d. *c.* 400/1109), author of *Kitāb al-taṣrīf*, translated into Latin under the title *Liber Servitoris*, dedicates one section (Book XXVII) to simples of which he gives an alphabetic inventory with lots of synonyms.[29]

Ibn Wāfid (d. 460/1068) wrote a work about simple drugs, translated into Latin by Gerard of Cremona under the title *Abenguefith de medicamentis simplicibus*.[30]

Al-Ghāfiqī wrote a treatise on simples which forms the basis of Ibn al-Bayṭār's dictionary.[31] Al-Sharīf al-Idrīsī (d. 560/1160) also wrote a *Treatise of Simples* used extensively by Ibn al-Bayṭār; he gives the synonyms of drugs in six to twelve languages and enumerates Iberian, Berber and Sudanic plants.

Maimonide, the famous Jewish doctor and philosopher, wrote a glossary on medical matter (*Sharḥ asmāʾ al-ʿuqqār*) edited, with a long introduction about Arabic texts relating to simples, by Max Meyerhof.[32]

A synthesis of these principal texts and many others was made in the seventh/thirteenth century by Ibn al-Bayṭār (d. 646/1248), author of the largest pharmacological encyclopedia that survived to our time. Under the title *Kitāb al-Jāmiʿ li-mufradāt al-adwiya wa-l-aghdhiya* (*Dictionary of Simple Remedies and Food*), Ibn al-Bayṭār gives in 1500 paragraphs a summary of the pharmacological knowledge of his time, basing himself on Dioscorides and Galen, the *Book of Simples* of al-Ghāfiqī, the works, today lost, of his teacher Abū al-ʿAbbās al-Nabātī (the Botanist), nicknamed Ibn al-Rūmiyya (d. after 636/1239), and numerous other botanical and agricultural works. 'The number of authors cited is about 150, that of drugs mentioned is 1400, of which 400 were unknown to the Greeks; they were introduced into the pharmacopeia by the Arabs.'[33]

### *4 The geographical sources*

Narratives about journeys and descriptions of countries contribute to enriching the nomenclature of plants amongst the Arabs. These contributions appear already in the *Nabatean Agriculture* where the travels of Adam to India and Ceylon are described in great detail with his numerous botanical descriptions and observations and the plants which he brought from these countries to Mesopotamia.

Among the Arab travellers whose reports include botanical data we can take as an example Ibn Baṭṭūṭa (d. 779/1377) who calls attention in his *Riḥla*[34] to everything that appeared to him as excellent, strange and wonderful in the vegetable kingdom. Thus he describes the excellent fruit of Isfahan, apricots, quince, grapes, watermelon (II, 44); the *tanbūl* or betel and coconut (*nārjīl*) of ʿUmān (II, 204, 206); the *kundur* or tree with Dhofar's essence (II, 214); a kind of millet called *dūghy*, the main food of the Turks of Azerbaijan (II, 364); the excellent watermelon of Khwārizm which is dried like the fig (III, 15); fruit trees of India – the mango tree (*ʿanba*), the *shekī* and the *berkī*, trees similar to ebony, the *gūmūn* (*tchoumoum* or *djambou*), sweet orange, the *mehwa* (*bassia latifolia*) etc. (III, 125 *et seq.*). He also tells us about the grains sowed by the inhabitants of India and which they also use as nourishment: the *khudhrū*, a kind of millet; the *kāl*, which resembles millet; the *shāmākh* (*panicum colonum*); the *māsh* (*phaeseolus max*); the *mung* (*mungo de Clusius*); the *lūbyā*, a kind of bean; the *mūt*, which resembles *khudhrū*, etc. (III, 130 *et seq.*).

In Malabar, a country which produces pepper (IV, 71), he calls attention to cinnamon (*jirfa*) and the Brazil nut (*baghgham*) (IV, 99). The main trees of the Maldives Islands are the coconut tree, the palm tree, the *tchoumoun* (*Eugenia Jambu*), the lemon tree, the lime tree, the colocasie (IV, 113). The main vegetable products from the Island of Java are benzoin, camphor, aloe and clove (IV, 240 *et seq.*). And so on.

We can collect similar data from many records of journeys and from geographical texts. If one considers a region of the medieval Islamic world such as Sicily, one learns that there were two wooded areas on this island: Etna and Apennino. The latter zone overhangs Cefalu; all kinds of wood used in ship construction abound.[35] The monk Nil, in the *Life of St Filareto*, praises the cedars of Sicily, the cypresses, the pine trees, straight and majestic; their branches are used to make torches because they are so resinous. Al-Bakrī and Yāqūt speak of the fertile produce of the gardens, the fields and pastures; there is no lack of fruit either in winter or summer. Ibn Ḥawqal who visited Sicily in 362–3/972–3 tells us that saffron grows spontaneously there, that cotton and hemp were cultivated in Giattini; he very much appreciates the cotton fabric from Sicily. There are numerous vegetables for cooking, he tells us. The Arabs introduced there the culture of orange trees and other citrus fruits which today are at the head of commercial products in Sicily; the culture of the sugar cane, the date palm and the mulberry tree are also due to them. Al-Idrīsī speaks of the abundance of silk produced in San Marco in the Val Demone. Particular mention is made of Sicily's onion concerning which Ibn Ḥawqal proclaims misdeeds on the Sicilians' intelligence. It seems that a kind of Sicilian onion went to Tunis; it is described by al-Bakrī as having the size of an orange, elongated, of thin and very juicy skin; he calls it *qalawrī* (from Calabria). According to Amari it is the *cipuda di Calavria*. Finally a flower, probably the rose mallow (*pelargonium radula roseum*) is called by the Sicilian Arabs *al-khubāzā al-ṣiqillī*, 'the Sicilian mallow'.[36]

The exploitation of the rich literature on Arabic geography and of numerous reports of journeys will certainly allow a better evaluation of the Arabic contribution to the history and development of botany.

## II The classification of plants

Since the *Nabatean Agriculture* is the main source and model for Arab agronomists, we thought we would find there the richest and most complete classification; we have therefore adopted it here.

The author of this treatise details seven characteristics supplied for each vegetable:

(a) a description
(b) the ground which suits it
(c) the time for planting and harvest
(d) the way of planting
(e) the tending that it requires
(f) the winds and seasons that suit it
(g) the manure that suits it and the treatments it requires
(h) its usefulness and harmfulness
(i) its properties[37]

Botanic matter is classified as follows.

A The aromatic floral plants (*Agr. nab.*: I, 111–41)
Ten plants are described.

1 Violet (*banafsaj*). The author describes the processes of planting (with figures), of acceleration of flowering, of utilization – notably for the manufacture of violet syrup. He enumerates the medicinal properties, indicates the nature of the ground to choose and describes the diseases to which this plant is exposed (al-Dīnawarī, no. 94).
2 Clove (*khīrī*), way of planting, varieties, way of manufacturing the essential oil (*duhn*) of clove (al-Dīnawarī, no. 346).
3 Iris (*sawsan*): it exists in four colours; way of planting and medicinal properties (al-Dīnawarī, no. 552).
4 Waterlily (*līnūfir*): Indian plant having medicinal properties; subject to jaundice (*āfat al-nujūm*).
5 Narcissus (*narjis*): way of planting; wonderful properties (al-Dīnawarī, no. 1043).
6 Anthemis (*uqḥuwān*): description; extraction of anthemis oil; properties (al-Dīnawarī, no. 14).
7 Jasmine and wild rose (*yāsmīn and nisrīn*), two sister plants each in two colours; way of planting; oil (al-Dīnawarī, no. 1110; 1085 *ward jabalī*).
8 Marigold (*ādharyūn*): description, comparisons with waterlily; properties (Bayṭār, I, 16).

9 The fetid buphtalme (*bahār* or *ward al-ḥimār*: rose bush): way of planting and properties (al-Dīnawarī, no. 698: *ʿarār*).
10 Mignonette (*khuzām*): love herb like the buphtalm with which, like the marigold it has affinities (al-Dīnawarī, no. 341: *khuzāmā*).

Other aromatic plants: the rose tree (*ward*), the alkekenge (*kākanj*), the chalef (*khilāf* (*balkhī*)), the flower of the wise men (*khatm al-majūs*) which is a variety of jasmine, marjoram (*marū*) with blue and white flowers, plants whose yellow flowers resemble birds or other flying animals, the buttercup (*shaqā'iq*), etc. (al-Dīnawarī, no. 1084 *ward*; 311 *ketmie*, 680 *kākanj*, 305 *khilāf*, 1018 *marū*, 589 *shaqā'iq*; Bayṭār, II, 148 *hūm al-majūs* = *marānyā*).

A certain resemblance between these plants justifies their grouping. Other aromatic plants will be mentioned in the following classifications.

The author of the *Nabatean Agriculture* described a certain number of aromatic plants growing in the desert after torrential rain, such as the *qaʿū*, the *daymarām* (al-Dīnawarī, no. 658), the *hawjām* (al-Dīnawarī, no. 231).

B Fragrant bushes and ornamental trees (*Agr. nab.*: I, 142–93)
Twenty-three plants are described.

1 Myrtle (*ās*), 'master of the aromatic plants': it reaches the size of a tree; description and varieties, medicinal properties. It is used in the mummification of corpses. An essential oil is extracted from it. Action against magic (al-Dīnawarī, no. 10).
2 Laurel (*ghār*): ground and wind suitable for it; affinities with the cedar; properties; dialogue with the guardian of an orchard (al-Dīnawarī, no. 779).
3 Castor-oil plant (*khirwaʿ*): description, medicinal properties; shade is good for the small plants.
4 The ketmie of Syria (*khaṭmī*): diseases and treatments; nature; numerous properties. Dispute with mandragora (*yabrūḥ*) (al-Dīnawarī, no. 311; no. 1111).
5 The terebinth (*buṭm*): description, nature, affinities with myrtle; medicinal properties (al-Dīnawarī, no. 74).
6 The berberine (*anbarbarīs*): plant of Babylon and Khurāsān. Description, way of planting; great usefulness, nature, properties (al-Dīnawarī, no. 54: *ithrār*).
7 The hawthorn (*zuʿrūr*): description, properties, diseases (al-Dīnawarī, no. 475).
8 Azedarach (*āzādrakht*), 'sister of hawthorn': way of planting; properties (treatment of hair).

9 The plane tree (*dulb*) is a non-fruit tree (see below, pp. 826 ff): description, properties; numerous tales about it (al-Dīnawarī, no. 383).

10 The chalef (*khilāf*): description, way of planting, properties, usefulness to other plants. Ornamental tree (category of tree called *shajar al-quḥāb*, 'trees of prostitutes') (al-Dīnawarī, no. 305).

11 The calotrope (*ʿushār*): tree from hot countries; description; 'sugar of calotrope'; ground and winds which suit it; diseases and treatments (al-Dīnawarī, no. 711).

12 The elm (*dardār*): description, properties.

13 The kermes-oak (*qirmiz*): originally from Byzantium; description. Tree from cold areas.

14 The phellodendron (*ʿayshūm*): ephemeral tree; description: flowers similar to roses of Rayy, with good aroma. It is used in the manufacture of bows and ropes. Nature and care (al-Dīnawarī, no. 776).

15 The banana tree (*mawz*): plant from hot countries; has only one cycle per year; requires a lot of care; diseases and treatments (long description, al-Dīnawarī, no. 1046).

16 The bitter orange tree (*nāranj*): originally from India; description, remedies; essential oil (Bayṭār, II, 174 mentioning the *Nabatean Agriculture*).

17 The cedar (*utrujj*): 'the pure tree'; description, properties, tending required; grafting, numerous medicinal properties (al-Dīnawarī, no. 46).

18 The lemon tree (*ḥasbnā*?): affinities with the bitter orange tree and the cedar; ground and tending that suit it; medicinal properties (Bayṭār, IV, 118–22: *līmūn*).

19 The laurel rose (*diflā*): 'the blessed tree'; poisonous oil; prophylaxis (al-Dīnawarī, no. 377).

20 The Syrian carob tree (*khurnūb shāmī*): description: gives small fruits in Babylon; properties; tales attached to it. Dialogue between the carob tree and the elm.

21 The sorb (*ghubayrā'*): description, wild plant originally from India; usage in magic, like mandragora and the ketmie; the aroma of its flowers is an aphrodisiac for women; properties (al-Dīnawarī, no. 783).

22 The common wild pepper (*shajarat Ibrāhīm*): description, ornamental tree appreciated in Sūrā, Babylonia; whence the name 'tree of Abraham'; numerous wonderful properties; affinities with the mandragora and the agrostemme (*sirāj al-quṭrub*); effective cosmetic; numerous wonderful properties.

23 Bramble (*ʿawsaj*): hedge used to form enclosures. Medicinal properties of prickly plants such as the bramble, the thistle (*shawk*), the marrube (*bādāward*), the cross of Malta (*ḥasak*), the cardoon (*kharshaf*).

In the category of wild shrubby trees, the author of the *Nabatean Agriculture* describes the jujuber of the East (*sidr*: al-Dīnawarī, no. 502), the caper (*kabar*: al-Dīnawarī, no. 928), the arak (*ārāk/isḥil*: al-Dīnawarī, nos. 1, 2), the tamarisk (*athl*: al-Dīnawarī, no. 4), the bitter fig (*tīn barrī*: al-Dīnawarī, no. 125), the *nabʿ* (*chadara tenax*: al-Dīnawarī, no. 1055), the wild banana tree (*ṭalḥ*: al-Dīnawarī, no. 669), the acacia forskal (*samar*: al-Dīnawarī, no. 535), the aurone (*qayṣūm*: al-Dīnawarī, no. 922), the piliselle (*shih*: al-Dīnawarī, no. 601), the juniper tree (*ʿarʿar*: al-Dīnawarī, no. 701), the sticky alder (*ṭubbāq*: al-Dīnawarī, no. 661), the wild aneth (*shibithth*: al-Dīnawarī, no. 565), the oily bean (*bān* or *shūʿ*: al-Dīnawarī, nos. 75 and 597), the anagyre (*yanbūt*: al-Dīnawarī, no. 1118), the stype (*ḥalfāʾ*: al-Dīnawarī, no. 251), the papyrus (*bardī*: al-Dīnawarī, no. 78), the aloe (*ṣabir*: al-Dīnawarī, no. 611), the tamarind tree (*ṣubbār*: al-Dīnawarī, no. 610), etc.

We have only transcribed a small part of the wild plants mentioned in the *Nabatean Agriculture* and in al-Dīnawarī because of the difficulty in their identification anu also because of the restriction in the number of pages for this explanation.

C Fruit trees (*Agr. nab.*: II, 1132–237)

The *Nabatean Agriculture* dedicates three large chapters to the olive tree (at the beginning), to the vineyard (in the middle) and to the date palm (at the end). They are really treatises, studying the ways of culture, the tending, the properties, the usefulness of these trees which occupy an important place in arboriculture. Then a long section is dedicated to other fruit trees of which the most important are as follows.

*(a) Fruits with a dry pericarp*

1 The grenadine tree (*rummān*): way of culture; modifications in the flavour of its fruit, usefulness and properties; diseases; properties (al-Dīnawarī, no. 455).
2 The walnut tree (*jawz*): description, culture, nourishing and medicinal properties; harmful consequences for throat and mouth; usefulness (al-Dīnawarī, no. 165).
3 The common coconut tree (*jawz hindī*): description; originally from India; nourishing and medicinal properties (al-Dīnawarī, no. 1053: s. *narjīl*).
4 The almond tree (*lawz*): sweet and sour, culture, medicinal properties of the bitters.
5 The hazel tree (*bunduq*): wild tree, also cultivated in orchards; way of culture, properties.

6 The pistachio tree (*fustuq*): culture; rapid tainting; nourishing and medicinal properties (al-Dīnawarī, no. 825).
7 The oak tree (*ballūṭ*): wild tree; medicinal properties of its acorns.
8 The chestnut tree (*shāhballūṭ*): wild tree planted in gardens; nourishing and medicinal properties.

*(b) Fruits with fleshy pericap*

9 The apricot tree (*mishmish*): culture, properties (fever), usefulness.
10 The peach tree (*khawkh*): the same culture and properties as the preceding tree; detergent power (al-Dīnawarī, no. 340).
11 The plum tree (*ijjāṣ*): the same culture as the preceding trees; stays acid in Babylonia; numerous varieties, properties and harmfulness (al-Dīnawarī, no. 49).
12 The *shahlūj*: variety of plum tree; quite different from the preceding one; less noxious.
13 The jujubier tree (*ʿunnāb*): legend about its origin; medicinal properties of its syrup (al-Dīnawarī, no. 754).
14 The buckthorn (*nabiq*): wild and horticultural; different varieties with or without stones; as hardy as the olive tree and the date palm; harmfulness; dialogue between two buckthorns.
15 The spondias (*al-ijjāṣ al-jabalī*): description; acid taste; juice used in cooking.
16 The arbutus (*qaṭlab*): wild and horticultural; nourishing and harmful properties.
17 The plum-cherry tree (*qrāsiyā*): originally from the banks of the Jordan ('Canaan tree'); a sweet is made from it.
18 The fig tree (*tīn*): numerous varieties distinguished by colour; description, way of culture, tending, nourishing properties, harm to avoid (al-Dīnawarī, no. 125). The sycamore-fig tree (*jummayz*): harm and treatments (*ibid.*).
19 The pear tree (*kummathrā*): numerous varieties; treatments against the rapid tainting of its fruits, to obtain more beautiful pears, and sweeter. Strong nutritive properties; damage, improvement by grafting; medicinal properties (al-Dīnawarī, no. 67).
20 The quince tree (*safarjal*): wild and horticultural, sour taste; is used to prepare an insecticide; nutritive properties; jam.
21 The apple tree (*tuffāḥ*): varied tastes; beneficial juice; growth of production; alimentary properties (fortifies the heart, is harmful for the brain; it is called 'enemy of reason').
22 The mulberry tree (*tūt*): different tastes and colours; ways of culture (by bird excrement); tending; properties (al-Dīnawarī, no. 127).

23 The pine tree (*ṣanawbar*): two varieties of kernel, big and small, imported from Syria; more a medicine than a food; medicinal properties (al-Dīnawarī, no. 630).

24 The cherry *mahaleb* (*ushtur kuhā*): wild tree cultivated in orchards; description; its grain (*maḥlab*) used in perfumes and drugs; aromatic oil with medicinal qualities; culinary usage (al-Dīnawarī, no. 1007: *maḥlab*).

25 The fir tree (*tannūb*): description; produces a white substance inside a greyish envelope at the junction of the nodes used in pharmacy; treated, it can be used as food (al-Dīnawarī, no. 128).

26 *Ḥ(u)bltā*:[38] tree wild and planted in towns; description; carries grains the same size as small pistachios with thick envelopes; grilled they become white. Used in the treatment of diseases of the mouth. Outside its envelope the cooked and salted grain is eaten with a drink like the almond and pistachio. Properties.

27 The cedar (*arzā*): description; carries grains at the nodes like chick peas, black outside, yellow inside; treated, they are consumed with honey, in spite of their bad smell, in countries where fruit is lacking; it closely resembles the male pine, which produces tar (al-Dīnawarī, no. 5: *arz*).[39]

28 The lycium (*fīlā zahrā*): description; its fruit in the form and size of chick peas; it is red; contains a grain. Medicinal properties (al-Dīnawarī, no. 286: *ḥuḍaḍ*; Ibn al-Bayṭār, II, 173: *fīlzahraj*).[40]

The date palm is not part of this list as a long treatise is dedicated to it at the end of the book. The same for the vine to which a long section is reserved in the heart of the compilation.

D Non-fruit trees (*Agr. nab.*: II, 1246–81)

1 The maple tree (*qayqab*): tree from Syria and from the country of the Greeks. Description; use in woodwork.

2 The nabatean poplar (*ḥawr nabaṭī*), a name given by the author to *ṣafṣāf*, 'willow', and to *khilāf*, 'eleagne' or 'chalef' (see above, p. 823, no. 10). It is probably the poplar tree of the Euphrates or the willow of Babylon (*gharab*). Description and properties (al-Dīnawarī, no. 305: *khilāf*; no. 550: *sawjar*).

3 The *shawḥaṭ* (*grewia populifolia* or *chaderatenax*: *nabʿ*): white wood traversed with black veins; it is used to manufacture the handles of knifes (al-Dīnawarī, no. 596).

4 The yew (*zarnab*): common tree in Syria; strong smell; wood with red veins.

5 The oak (*sindyān*): description; use of the wood; same leaves and same wood as the *ballūṭ*.[41]

6 The cistus (*qisṭ*): grows in India and the West (Arabia); the Syrian type is of an inferior quality. Description; use in fumigation in worship. Use in perfume; properties (Bayṭār, IV, 18–19).

7 The cinnamon tree (*salīkha*): numerous varieties; description; good smell, bitter taste; imported from the West (Arabia). Culinary and pharmaceutical use (Bayṭār, III, 25 *et seq.*).

8 The amome cardamom (*ḥamāma*): grows in the Kurd country. Use in pharmacy; medicinal properties (the *amōmon* from Dioscorides).

9 The Valerian phu (*fū*): good and strong smell and taste, similar to ginger; pharmaceutical use (Bayṭār, III, 168 *et seq.*).

10 The citronella or sweet calamus (*idhkhir*): plant from Ḥijaz where it grows in tufts (al-Dīnawarī, no. 21).

11 The spiky cistus (*rabakshānā*?): grows in Babylonia: use in perfumes (Bayṭār, II, 85: *dār shīsha'ān* (Persian), *qundūl*).

12 The myrrh tree (*murr*): thorny Arab tree; description; used in perfumes and in pharmacy; properties; its wood is used in worship (al-Dīnawarī, no. 1011).

13 The oliban (*kundur*): its resin dried out on stems is collected and sold by the Arabs and used in fumigations in front of idols. As mastic, it has numerous medicinal properties; it fights epidemics. Useful, notably for colds (al-Dīnawarī, no. 971, no. 979: *lubān*).

14 The lycium of Arabia (*ḥuḍaḍ*): bush from the desert; from its leaves is extracted a bitter sap which solidifies like myrrh and gums, used in pharmacy. The island of Ceylon produces a distinct variety of the lycium of Arabia. Description; medicinal properties (see above, p. 826, no. 28).

15 The acacia (*aqāqyā*): four distinct varieties according to their size. Description. From its fruit, and from the fruits and leaves together, a sap is extracted which is used in pharmacy; it produces a gum collected and sold everywhere. Tree from hot countries. Medicinal properties (al-Dīnawarī, no. 669: *ṭalḥ*, *acacia gummifera*).

16 The sumac (*summāq*): description; one can extract from its fruit and leaves a sap analogous to that of the acacia; used in particular in cooking and also in pharmacy as a hair treatment (al-Dīnawarī, no. 534).

17 The carissa (*qārīthā*, ar. *qāris*): 'sister' of the sumac but bigger and more common; a similar leaf to the olive tree; the fruit is produced without previous flowering, similar to the pistachio, without pericarp; it gets red and sweeter on maturing; eatable but astringent.

18 The cistus ladaniferus (*lādhan*): prickly cistus. From the sticky wetness of its leaves one extracts ladanum (*lādhin*); sticky sap and powder. Similar to the black alder; use in pharmacy (better treatment for hair). Medicinal properties (al-Dīnawarī, no. 977).

19 Henna (*ḥinnā*): plant from hot countries. Description; use in cosmetics and pharmacy. Properties (al-Dīnawarī, no. 207).

20 The *mrūṭā* (non-identified tree): reaches about 1.20 metre; leaf similar to the almond tree, fruit like the bean, containing two grains, rarely three; fruit round and black turning red, not eatable because of its bad smell; underneath the ground it becomes sweeter and eatable. Two fingers away from the root, the stem forms a single shoot with two big square leaves, sometimes one big and one small; the shoot carries a flower similar to the flower of the pomegranate tree; after the fall of the flower appears a green vegetable turning yellow as long as a small asparagus, with a sweet flavour, eatable. Used in cosmetics.

21 The tamarisk (*ṭarfā*): description, description of two varieties resembling it: the *tamarix campanulata* and the *tamarix mannifera*. Used in dyeing (al-Dīnawarī, no. 667).

22 The ash (*murrān*): description; medicinal properties; poison and antidote against poison (al-Dīnawarī, no. 1013).

23 The storax (*sṭūrkā*): description; produces the liquid styrax (*al-mayʿa al-raṭba = al-lubnā*); used as incense in the temples and in perfumes. Medicinal properties (Bayṭār, IV, 171: *mayʿa*).

24 The tree of blue balm (*muql azraq*): similar to the storax: gum collected by the Arabs and sold in Syria and Babylonia. Use in pharmacy and perfumes (al-Dīnawarī, no. 1038).

25 The meum or wild aneth (*mrāq/fās*?; ar. *mū*): description; strong smell; common in Sudan; grows in Arabia; introduced in Babylonia (Bayṭār, IV, 168: *mū*).

26 The savin juniper (*abhal*): three varieties (one in India, two in Persia, Arabia, Africa); description; use in pharmacy, cooking and perfumes; medicinal properties (Bayṭār, I, 6–7).

27 The corchorus olitorius (*mulūkhiyya*): description; culinary use; medicinal properties (Bayṭār, IV, 166).

28 The prickly paliure (*shabahān*): description; produces a red flower to which succeeds a grain as big as that of the hempseed, from which one extracts viscous sap very effective in poisonous bites. It soothes the throat and chest (al-Dīnawarī, no. 570).

29 The box tree: description (in two paragraphs: s. *baqs(īr)* and s. *shamshār*); its wood is used to make trays, small boxes and other utensils (Bayṭār, I, 103: *baqs*).[42]

Concluding this list, the author tells us that, in view of the large number of wild and cultivated non-fruit trees, he chose some specimens of trees growing in Babylonia or imported in this region.

There follows what we can call a treatise on arboriculture, a long explanation on grafting of trees. The author describes various specimens on the subject and states the principles on which this science rests. He gives precise examples of certain grafts with unexpected effects (*Agr. nab.*: II, 1281 ff).

E Leguminous plants and graminaceae (*Agr. nab.*: I, 406–638)

*(a) Cereals and starches*

1, 2 Wheat and barley (*ḥinṭa* and *sha'īr*): long expositions are dedicated to these two cereals whose culture was very important in Babylonia at this time. In addition to the choice of suitable ground for cereals and their prophylaxis, the author considers all aspects of their culture, from sowing to harvest. He speaks of the different ways of storing them, the signs of tainting, the washing of the grains, the bran and the flour and their medicinal properties, the best bread, the rich properties of cereals, the herbs which resemble them (cockle, false rye), etc. (al-Dīnawarī, nos. 256 and 584).

3 Rice (*uruzz*): nourishment for the inhabitants of India and the banks of the Indus. Suitable ground; planting procedures; summer rice and winter rice. Nourishing properties; culinary use; medicinal qualities; rice bread (al-Dīnawarī, no. 70).

4 Rye (*jāwars, dukhn*): description; affinities with rice; way of planting, rye bread (al-Dīnawarī, no. 405).

5 The broad bean (*bāqillā*): culture and care; vermifugation; time and method of planting; diseases and remedies; uses and harmful effects; multiple properties; bean bread (al-Dīnawarī, no. 87).

6 The bean from Angola (*māsh*): affinities with the broad bean; it is cultivated in the same way; medicinal properties (al-Dīnawarī, no. 1000).

7 The lentil (*'adas*): mode of culture; bad herbs growing with it; cooking; nutritive properties (al-Dīnawarī, no. 692). In the section on vegetables a passage is dedicated to a plant which grows with the lentil, eatable and having medicinal properties.

8 The ers (*kirsanna*): description; medicinal properties; fodder for animals; medicine for man (al-Dīnawarī, no. 940).

9 The chick pea (*ḥimmiṣ*): description; how to make the grain grow? Properties (al-Dīnawarī, no. 255).

10 The vetch (*julubbān*): affinities with the broad bean: properties (al-Dīnawarī, no. 207).

11 The cinquefoil (*masjūthā*?, Bayṭār; syr. *meshḥūnā*): plant from Khuzistan and Fars; affinities with the chick peas; medicinal properties; cures scurf and freckles (Bayṭār, III, 35: *saksanbūna*).

12 The dolic (*lūbyā*): red and white; spring dolic, winter dolic; tending, cooking; properties. Originally from China (al-Dīnawarī, no. 995). In the section on vegetables there is a variety of dolic called *shamīla wa al-shabīh*, whose fruit resembles kidney beans. Description; culinary use.

13 The lupin (*turmus*): Coptic plants; bitter; properties; sweetening procedures; bad herbs growing with it; properties (al-Dīnawarī, no. 130).

14 The trigonelle (*hulba*): mode of culture; prophylaxis; medicinal properties; laxative, effective remedy against enteroxaems (al-Dīnawarī, no. 229).

15 The *yūlūrīthā* (?): a variety of trigonelle; affinities with barley; looked for by the birds.

16 The triticum (*ḥūbīthākōy*?): affinities with trigonella; description; triticum bread; dermatological properties (Bayṭār, II, 78: *khundrūs*).

17 The *ṭarmākī* (large wheat: *triticum turgidum*?): affinities with epeautre; cultivated in the region of Bārimmmā and Takrīt; properties.

18 The *thrūmīshā* (*bromus*?): imported from the country of the Greeks. Description; flourishing in Babylonia; bread of inferior quality of wheat bread. It needs manure. Medicinal property.

*(b) The oil seeds (except for the olive tree to which a treatise is dedicated at the beginning of the work)*

19 The hemp (*thūnīghā*, 'tung'): produces the *shahdānaj*, hempseed; oil of hempseed; numerous uses. Imported from India (Bayṭār, IV, 39: *gunnab*).

20 The cotton tree (*quṭn*): description; suitable ground and winds, harvest; medicinal properties (al-Dīnawarī, no. 898).

21 Linen (*bazr kattān*): Coptic plant; very widespread. Description, way of planting; properties (al-Dīnawarī, no. 929).

22 Sesame (*simsim*): mode and time of culture; prophylaxis; medicinal properties (al-Dīnawarī, no. 538).

*(c) Other plants with grains*

23 The cultivated lotus (*ghālālūtā*?): originally from Egypt. Description; affinities with the broad bean; bread; culinary use.

24 The sesban (*saysabān*): 'tree with leguminous fruit'; its grains are used for bread and in cooking. The Persians call it *panjankusht* (vitex), because its branches grow from the trunk in groups of five; consumed in particular by the Kurds in Azerbaijan. Medicinal and magic properties similar to those of the common 'tree of Abraham' (see above,

p. 823, no. 22) (al-Dīnawarī, no. 556; Bayṭār, I, 115–16: *panjankusht*; III, 46: *saysabān*).

25 The poppy (*khashkhāsh*): three paragraphs are dedicated to this plant. The first concerns its varieties: white poppy and black poppy; description of the wild poppy and the cultivated poppy, the first one being more effective than the latter; numerous properties of the white poppy from which one can make bread. Medicinal properties: sleeping drug and tranquillizer (al-Dīnawarī, no. 374).

F Vegetables (*Agr. nab.*: II, 761–914)
This section is divided into two large parts.

*(a) Vegetables with onions, rhizomes, grains*

1 The common asparagus (*halyūn*): description; one can make bread from it; culinary use; prickly plant. Medicinal properties (Bayṭār, IV, 195–6). Later, it describes a plant similar to the asparagus, originally from the country of the Greeks or Egypt. Description and culinary use.

2 *Hadhrat/thāyā* or *hadrayānā* (?): plant imported from the banks of the Jordan; affinities with asparagus; grains and stems milled together can be used to make bread; culinary use. Mixed with beans and seasoned it is a dish that is believed to have been eaten on the eve of the birth of a child (*ʿid al-mīlād*) (of the sun?) in order to avoid summer fever.

3 *Atūnīshāthā* or *anūnīshāthā* (?): plant imported from India; affinities with rape. One can use it to make bread. Culinary use; medicinal properties: aphrodisiac.

4 Rape (*saljam*, name meaning 'rape' now): description; culinary use; nourishing and medicinal properties; bread; rape juice (acid) used as seasoning. Two varieties are described: wild rape and a finer variety than the cultivated one whose name has not yet been identified (al-Dīnawarī, no. 529).

5 The Syrian radish (*fijl shāmī*): affinities with rape; description; nourishing and medicinal properties (al-Dīnawarī, no. 817).

The elongated radish (*fijl mustaṭīl*): similar to the preceding one in many aspects; culinary use; medicinal properties. Wild radish more effective than the cultivated one. Medicinal properties.

6 The carrot (*jazar bustānī*): two varieties; description; nourishing properties; culinary use; carrot juice (al-Dīnawarī, no. 186).

The wild carrot (*jazar barrī*): description, culinary use; medicinal properties; aphrodisiac (al-Dīnawarī, no. 228: *ḥinzāb*).

7 The glandulous alder (*rāsan*): description; culinary use; medicinal properties.

8 The Syrian leek (*karrāth shāmī*): two varieties. Description; planting; culinary use; properties (al-Dīnawarī, no. 436).

9 The onion (*baṣal bustānī*): three varieties. Description, culture; properties; culinary use; onion oil; numerous superstitions attached to it. The onion called *balīs/sha* (bulb?): widespread in Mesopotamia; more bitter than the common onion; very strong odour; culinary use; properties. The wild onion (*baṣal al-zīr*: muscari botroyoide): wild plant cultivated in kitchen gardens; culinary use; properties; aphrodisiac (al-Dīnawarī, no. 111).

10 The squill (*baṣal al-fār*, called *ishqīl/ gr. sqīlla* and *ʿunṣul*): big white onion; flourishing in cold and mountainous countries (Andalusia, Byzantium, Syria, Khurāsān). The Arabs call it *baṣal al-bar(rānī)*. Its juice is used to prepare a poison for rats. It is not edible but one can extract a kind of vinegar for seasoning; different procedures of extraction. Numerous medicinal properties (al-Dīnawarī, no. 761: *ʿunṣul*).

11 The shallot (*ʿa(s)qalānī*, from Ascalon): affinities with the onion called *balīsa* (see above, no. 9); description; it is as strong as the squill; same properties as that.

12 Garlic (*thūm*): Babylonian plant exported to Egypt since ancient times to Egypt. Numerous tales about its origin. Numerous medicinal properties; antidote for serpent bites, for rabies ... (al-Dīnawarī, nos. 156 and 160).

13 Rose garlic (*f/qarūṣiyāhā = qirṭ?*): cultivated in the low plains of the Euphrates; affinities with the Syrian leek and garlic; culinary use; numerous properties.

14 Vine garlic (*shūmkarrāth*): description; more pungent than the leek; properties.

15 *Farshūqiyya* (?): plant called, in the plains of the Euphrates, significantly, 'similar to two testicles' or *khunthā*; 'hermaphrodite' with Eastern Greeks, *isqūlānūs* (compare above, no. 11); in Rome, *kundurūsakūs*; in Andalusia, *kasīlt/bākā*. Description; double onion; affinities with garlic and onion; culinary use; properties.

16 The common serpentaria (*lūf*): description; culinary use; medicinal properties (al-Dīnawarī, no. 996). A plant whose root resembles that of the serpentaria, is consumed in particular by the Kurds in the area of ancient Ninive, between the two Zabs. Description; culinary use; properties.

17 The muscari (*ḥalḥal makthā*, 1. probably *miskī*): description; culinary use; properties (Bayṭār, II, 29: *ḥalḥal = baṣal al-zīr*; see above, no. 9).

18 *Arīsārūn* (1. probably *arīghārūn*: erigeron): description; culinary use; medicinal properties.

19 The black truffle (*dā/ūrūmīqā?*): description; root similar the cucumber; culinary use.

20 The lycoperdon (*faqʿ*): comparable to the truffle; description; culinary use (al-Dīnawarī, no. 634: *fuqāʿ*).

21 The truffle (*kam'a'*): description; genesis; indicatory plant; nutritive properties; culinary use; truffle bread (al-Dīnawarī, no. 966).

22 The mushroom (*fiṭr*): description; numerous varieties, all poisonous (al-Dīnawarī, no. 832).

23 The morel (*ʿuṭlub*): description; culinary use (Bayṭār, III, 152, *ghawshana*).

24 *Al-umṭā nahrā* (?): formed underground in the sand or next to water, the first is red, the second black; resembles crumbs of bread. Called by the Arabs *khubz al-kalb*, 'dog's bread'. It is generally found close to the mandragora. Culinary use; numerous properties.

25 The spinach beet (*silq*): several varieties; description; mode and time of planting; culinary use; beet juice; beet bread. Properties: erases ink, detergent power, absorbs the salt from the ground. Medicinal properties (Bayṭār, III, 267; compare al-Dīnawarī, no. 946: *kurumb*).

26 Lettuce (*khass*): description; varieties; culinary use; medicinal properties (al-Dīnawarī, no. 336).

27 The wood-sorrel (*ḥummāḍ*): description; varieties; properties; similar culture to that of beet (al-Dīnawarī, no. 242).

28 The watercress (*qardamānā* = *qurrat al-ʿayn*): description; culinary use (Bayṭār, IV, 9).

29 The cuckoo flower (*qurdumānā* = *ḥurf*): similar to the preceding one; description; culinary use; medicinal properties (Bayṭār, IV, 7; al-Dīnawarī, no. 276).

30 The edible stump or ground almond (*suʿd*): description; culinary use; treatment to take off the skin (al-Dīnawarī, no. 512).

31 The lys (*sawsan* instead of *zanbaq*): description; four varieties; perfume; medical and even nourishing use if necessary (see above, p. 821, no. 3).

32 The aromatic reed (*wajj*): comparison with the lys; agreements and disagreements; rhizomes (Bayṭār, IV, 188).

33 The wild spikenard (*asārūn*): description; root with aromatic rhizomes roots; culinary use (Bayṭār, I, 23–4).

34 The spikenard from India: grows readily in India and little in Syria; flowers in spikes. Description; perfume similar to cyperus; culinary use.

35 The valerian of gardens (*fū mashhūr*, 'common phu', *asārūnā barriyya*, 'wild valerian'); wild plant cultivated in gardens in Babylonia. Description: knotty stem and root; medical and culinary use (Bayṭār, III, 168–9: *fū*).

36 The saffron (*za'farān*): description; use in dyeing and perfumes; numerous properties; its 'onions' do not seem to be edible; to try (al-Dīnawarī, no. 461).
37 The big alder (*zanjabīl shāmī*): thick black aromatic root; description; use in fumigations; conservation; adaptation of the rhizomes for consumption (al-Dīnawarī, no. 476).[43]

*(b) Vegetables with edible leaves and fruit*

38 Chicory (*hindabā*): the most useful of all the vegetables. Horticultural and wild, each having two varieties. The horticultural varieties are edible, the wild varieties have medicinal properties. Wild plants which resemble them; their medicinal properties (al-Dīnawarī, no. 1104, no. 874: *qishnīza*).
39 Mint (*na'na'*): several horticultural and wild varieties; numerous medicinal properties. Mode of culture and care (al-Dīnawarī, no. 1071).
40 Basil (*bādhārūj*): three varieties; quick therapeutic effects; harmfulness. Time of culture; grafting on varieties of lophosperme (*lā'iya*); balance of two opposed qualities. Medicinal properties (al-Dīnawarī, no. 292: *ḥank*; no. 656: *ḍanmarān*; no. 561: *sāhasfarm*).
41 Rocket (*jarjīr*): horticultural and wild, each with two varieties. Description; culinary use; medicinal properties; harmfulness (al-Dīnawarī, no. 199).
42 Ash (*karafs*); six varieties; culinary and medicinal properties. The wild variety is of three kinds: description, properties and harmfulness; culinary use.
43 The rue (*sadhāb*): horticultural and wild. Description; cultured twice a year; tending, watering, determined by researched properties. Numerous medicinal properties: remedy for epilepsy; it is harmful if overdosed; medicinal plant, non-edible. Wild rue more active (al-Dīnawarī, no. 504).
44 Watercress (*ḥurf*): three common varieties; a rare black variety (*sindī*); mode of culture and care; culinary use; medicinal properties (al-Dīnawarī, no. 276).
45 The black mustard (*khardal*): 'vegetable of magicians'; mode of culture; culinary use.
46 The wild chervil (*sqandāq = scandix*): wild vegetable with strong flavour; culinary use; medicinal properties; mode of culture.
47 The pennyroyal (*qūsālā*, probably the syr. *qūrnītā*): description; edible vegetable; medicinal properties. Imported from Egypt.
48 Water pepper (*zanjabīl al-kalb*); description; widespread in Armenia and Persia; the sap is sold; culinary use (Bayṭār, II, 168).

49 Medicinal hyssop (*jasmā*): description and culture; medicinal properties; nourishing use (Bayṭār, I, 163).

50 The citronella (*bādranjbū* = *al-baqla al-utrujiyya*): plant of the Persians, 'the blessed herb'. Culture; medicinal properties; culinary use (Bayṭār, I, 74–5).

51 The *zanbāq* (compare with the Persian *zanbān* meaning anise): planted between Baghdad and Wāsiṭ; imported from Rayy where it is widespread. Culture; culinary use; medicinal properties (Bayṭār, II, 168, *zanbā*).

52 The melilot (*ḥandaqūqā*): description; horticultural and wild; medicinal properties; harmfulness; culture (al-Dīnawarī, no. 248: *ḥabāqā*).

53 The aneth (*ḥazā*): culture; description; medicinal properties (al-Dīnawarī, no. 235).

54 The leek of Babylon (*kurrāth bābilī*): cultivated in autumn; several plants resemble it. Description; harmfulness; medicinal properties; improvement of flavour. The best remedy for haemorrhoids. Several properties are described. Leek from Sogdiane (*kūdhyān*): description; widespread in Sogdiane; culinary use and nourishing properties. The *kīlakān*; varieties of leek which grow between Rayy and Khurāsān. Nourishing qualities; culinary use. The *laslāsa*: variety of leek from Babylonia, called *al-mayyār*. Used in the preparation of three dishes. The *an kīh*: grows in Low Mesopotamia; exported to Persia; more effective than the others. Medicinal properties; culinary use.

Leek from Farghāna (*khaḍrawāyā*), called *barsūk*. Wild plant greener than the other varieties of leek. Culinary use; properties (Bayṭār, IV, 61–3).

55 The thyme (*ṣaʿtar*): numerous horticultural and wild varieties. Description; culture; properties (al-Dīnawarī, no. 615).

56 The persicaia (*barsiyānā*): Persian plant. Description; medicinal properties (Bayṭār, I, 38).

57 The clove (*qaranful*): two varieties; imported from India; description; medicinal properties. Culinary use (al-Dīnawarī, no. 868).

58 Tarragon (*ṭarkhūn*): description, behaviour and properties (al-Dīnawarī, no. 666).

59 *Dabīdāryā*: herb imported from India; description; culinary use. Its stem is chewed by the Indians; beneficial effects for the gum; medicinal properties (Bayṭār, II, 87).

60 Rhubarb groseille (*yaghmīsā* = *rībās*): description; medicinal properties (Bayṭār, IV, 209; II, 147).

61 'Herb of Egypt' (*yarqā miṣrā*), 'noble herb': imported from Egypt. Description: similar leaf to that of the carrot and similar flavour to fennel; medicinal properties.

62 'Herb of the country' (*yarqā qaṭrā*): Persian plant, growing mainly in Ḥulwān; the Persians call it *kannhān*, 'plant similar to the juniper'. Its leaves and smell resemble terebinth. Description, culture, culinary use, medicinal properties; effective against scorpions.

63 Amaranth (*yarqā karsa = marmāḥūr = baqlat al-jawf*): one of the seven varieties of *marw*. Detailed description on the latter; distinctive sign of each of the seven varieties; medicinal properties (al-Dīnawarī, no. 1018; Bayṭār, IV, 1489).

64 Coriander (*kuzbura*): culture and manure; medicinal properties; different opinions about it (al-Dīnawarī, no. 949; Bayṭār, IV, 66–70).

65 The purslane (*al-baqla al-layyina*): different names; culture; numerous medicinal properties (al-Dīnawarī, no. 423: *rijla*).

66 The spinach (*isfānakh*): description; culture; culinary use; nutritive properties; medicinal properties. Consumed regularly by the inhabitants of Ninive to fight diseases of the throat and bronchitius; 'blessed vegetable' (Bayṭār, I, 25).

67 The wild spinach (*qaṭaf*) or orach of the fields; wild plant cultivated in gardens; medicinal and nutritive properties more accentuated than in the spinach (al-Dīnawarī, No. 897: *qaṭafa*).

68 The orach (*sarmaq*): horticultural and wild (*qaṭaf*): description; properties; widespread in Ethiopia, Nubia and Sudan; consumed by the Negroes despite its bad smell.

69 The amaranth beet (*al-baqla al-ʿarabiyya* or *yamaniyya*): imported from Yemen; culture; medicinal and nutritive properties (Bayṭār, I, 103–4).

70 The aquatic patience (*ḥummāḍ al-mā'*): description; nutritive and medicinal properties; grows abundantly in Rās al-ʿayn (in Mesopotamia), where a scholar wrote a book on the properties of plants, attributing to this plant properties close to the mandragora and opposed to those of the tribule terrestre (*quṭrub*) (Bayṭār, II, 33).

71 The mallow of the gardens (*al-khubbāzā al-bustānī*): horticultural and wild; culture; nutritive and medicinal properties (Bayṭār, II, 467; al-Dīnawarī, no. 350).

72 The dandelion (*ṭarkhashqūq/ūn*): plant of the desert and arid zones transplanted into gardens; description; culture; the wild one is bitter; the most useful of vegetables; properties (al-Dīnawarī, no. 1115: *yaʿḍīd*; Bayṭār, III, 198–200: *hindabā barrī*).

73 The elegant acantholinon (*qanābrī*): similar leaves to the dandelion; grows spontaneously especially in gardens and along channels. Description, culinary use; medicinal properties (al-Dīnawarī, no. 809: *ghumlūl*).

74 The panicle (*shindāb*): strong resemblance with the two preceding plants (nos 72 and 73); grows spontaneously; same culinary use; medicinal properties (Bayṭār, IV, 12–13: *qurṣʿanna*).

75 'The herb of the sand' (*baql al-raml* or *al-birāthī*): grows in the deserts; strong resemblance with the preceding plant (no. 74). Description; properties; culinary use; collected and sold by the Arabs at the end of April, beginning of May. Wonderful qualities; properties of its roots (Bayṭār, I, 104).

76 The trigonella (*ḥulba*): culture; culinary use; medicinal properties (al-Dīnawarī, no. 229).

77 The dodder (*kushūth*): description; culinary use; medicinal properties; inconveniences (al-Dīnawarī, no. 956).

78 The fumitory (*shāhatraj*): description; culinary use; numerous medicinal properties (Bayṭār, III, 47–8).

79 The cabbage of Khurāsān (*kurunb khurasānī*): imported from Babylonia; description; medicinal properties.

80 The hippomaratre (*barhilyā*: grain of fennel, *rāziyānaj*): imported into Babylonia of Climate of the Sun, whence its name 'son of the sun', i.e. 'gift of Jupiter'. Eating it every day guards against all diseases and maintains health forever; the dead body will not smell bad. Treatment to follow to avoid incorruptibility of the body after death, which remains a gift of the gods. Description; medicinal properties (Bayṭār, II, 184–5: *rāziyānaj*; al-Dīnawarī, no. 90: *basbās*).

81 The aneth (*shibith*): wild and horticultural; sowed as a vegetable in Low Mesopotamia; culture; culinary use; medicinal properties (Bayṭār, III, 50–1; al-Dīnawarī, no. 566).

82 The alfalfa (*raṭba*): used as fodder; similar to melilot (see above, p. 835, no. 52). Description; culinary use in Babylon, food for the Kurds, inhabitants of Ninive. Nutritive and medicinal properties (al-Dīnawarī, no. 46). Two plants similar to alfalfa are described; their names are not identified.

83 The rape-cabbage (*kurunb*): horticultural, wild and *jazarī*. Description; a fourth variety with salty and bitter taste existed in Egypt. A sea variety (seakable) is quite different from the others. Culinary use; nutritive, medicinal and wonderful properties (al-Dīnawarī, no. 946).

84 The bindweed (*lablāb*): in the wild it is bitter and disagreeable to taste but a treatment described at length makes it an edible vegetable. Nutritive and medicinal properties (al-Dīnawarī, no. 982).

85 Variety of truffle (*kashanj*): edible stem, consumed by Babylonians, Sogdiens, Turks. Description; culinary use (al-Dīnawarī, no. 954). Nine edible stems growing in Babylonia are described next; their names have not yet been identified.

86 The cauliflower (*qunnabīt*): big, medium and small. Description; culture and care. Treatments to take away the bitterness in the small variety; nutritive properties; produces a bad chyme; other harmfulness. Culinary use; treatment against worms and insects (Bayṭār, IV, 59–61: *kurunb*).

87 The aubergine (*bādhinjān*): legend about its occultation. Advantages and inconveniences; mode of culture; nutritive properties; culinary use; interdiction of consuming it raw or even grilled (al-Dīnawarī, no. 115).

88 The marrow (*qarʿ*): pumpkin; mode of culture; time and place; care; the variety growing close to stagnant sweet water has medicinal properties which are the object of numerous tales; the variety growing close to salty water is harmful. Nutritive and medicinal properties; culinary use (Bayṭār, IV, 9–10).

89 The serpent cucumber (*qiththā' bustānī*): lunar plant. Description, culture and care; treatment to take away the bitterness; modification of properties of plants or 'transfer' (*naql*). Nutritive and medicinal properties (al-Dīnawarī, no. 853).

90 The cucumber (*khiyār*): comparable with the preceding one; more accentuated properties. Prevention against defects (Bayṭār, II, 80–1; al-Dīnawarī, no. 852: *qatad*).

91 The watermelon (*biṭṭīkh*): classified among the vegetables or among the fruits. Numerous varieties whose culture extends from March to the end of July; much tending; mode of culture; diseases which affect it; multiple variations due to atmospheric conditions; harmful consequences; prophylaxis. Sweetening procedures; grafting on the brambles, the ketmie, the liquorice, the fig tree, the mulberry tree. Trees whose neighbourhood is beneficial or harmful. Numerous tales about it (music and singing sweeten it); magic properties to give marvellous properties to the grains of the watermelon. Medicinal and nutritive properties. Prevention of defects (al-Dīnawarī, no. 110).

G The olive tree, the vine, the date palm

To these six sections, within which are distributed the plants (floral plants, fragrant bushes and ornamental trees, fruit trees, non-fruit trees, leguminous plants and graminaceae, vegetables), three other sections are added dedicated to the olive tree (at the beginning), the vine (in the middle) and the date palm (at the end). They are real monographs detachable from the whole and constituting complete manuals for the culture, care and exploitation of the three nutritious trees which played a major role in the economy of ancient and medieval Mesopotamia. The limits of this chapter on Arabic botany do not allow us to cover these three sections in depth. Let us note schematically the contents of the treatises.

(a) The olive tree (*zaytūn*) (*Agr. nab.*: I, 36–53): the beginning of this section is missing. The exposition starts with the required conditions for the culture of the olive tree (country, winds, weather, modification of the taste, remedies); the properties: the roots, leaves, ashes, oil, nuts; olive juice. Poems praising the olive tree (al-Dīnawarī, no. 466).
(b) The vine (*kurūm*) (*Agr. nab.*: II, 915–1132): the treatise starts with a quotation from a poem on wine attributed to Gilgamesh(?). There follow considerations about the action of wine on the soul. Choice of the ground as a function of the variety to be planted. The climbing vines. Time for culture; planting; orientation with regard to the wind, flood, optimization of the yield (use of burning mirrors). Harmful winds (poem from Māsā al-Sūrānī); prevention against atmospheric nuisances and insects; diseases and remedies. The theriacal vine (Bayṭār, IV, 56–7).
(c) The date palm (*nakhl*) (*Agr. nab.*: II, 1339–453): 'sister of Adam'; genesis of species; mode of planting and varieties; the 'loving' palm; aspirations towards salinity. Diseases and treatments; transfer of the sapling; superiority of the date palm over other vegetables. Noxiousness; handmade products made from the date palm. Numerous properties of the date, the palmite, the peel, the spathe, the white powder over the tender palms close to the heart. Nourishment and medicine for the Arabs; effects on the physical and moral state (al-Dīnawarī, no. 1061, pp. 293–324).

### III The phytobiology and morphology of plants

In the middle of this great compilation we find a section with a theoretical character which we can entitle 'Phytobiology and morphology of plants'.[44] In this section five important questions are studied (*Agr. nab.*: I, 663–759).

A The genesis of plants and their diversification. In this part is studied in particular

- (a) the causality and finality of the vegetable kingdom from the four elements;
- (b) the diversification of plants and the constitution of species;
- (c) agreements and disagreements;
- (d) the role of soil in the morphological modification of the plants.

B The genesis and cause of smells[45]
C The genesis and cause of flavours[46]

D The genesis and cause of smells.[47] Note that this section involves psychotherapeutic use of the colours of plants.

E Problems of structural morphology and plant biology. Among these problems the following are studied in particular.

(a) The roundness in the different parts of the plant, the length, the difference in leaves and branches, the quadrangular form of the stems, the branches, the leaves and branches of some vegetables.
(b) Why certain plants remain small and ephemeral while others grow and live for a long time. This is explained by the proportions in the mixture of the four elements, proportions which are equally at the origin of the formation of the essential oil and of soil in the plants.
(c) The transmutation of the elements into vegetable products (oil, vegetable fat, wine, etc.). It is either the consequence of a natural predisposition (e.g. the chicken, the egg and the chick, through the intermediary of heat; the olive tree, the ground and the oil through the intermediary of water), or the result of a specific action of one of the elements, in particular fire, by organic cooking (whence the juice, the sap, the fat, etc.).
(d) The perfection of the compound bodies, which is explained by the quality of the proportions of the elements in them.
(e) The death and decomposition of vegetable matter due to extinction in it of biological heat, exactly as in animals.
(f) The properties of plants in relation to animals and minerals for which it serves as an intermediary.
(g) Analysis of the symmetry and asymmetry in the disposition of the fruit and branches, caused by the equal or unequal action of the elements.
(h) The foliage: superfluous in the nourishment of the plant; produced by organic cooking. Its fall results from an excess of dryness; its return is due to the conjugated action of heat and wetness.
(i) The fructification is the result of the action of heat on the nourishment received by the plant. Important role of the kernels. Answers are given to the following questions: why are fruits on the extreme parts of the tree? Why are some fruits on the same tree bigger than others? Why are some fruits grouped in a covering while others are isolated? The reason for the coverings. The sexual differentiation in plants and their diverse manifestations.
(j) The gums and resins are the excess of the plant sap.
(k) The cause for the formation of thorns is to be found in the superfluity of two humid elements, water and air.

(l) The transformation of sap into milky juice is produced according to degree of organic cooking.
(m) The dosage in the natural qualities and the composition and properties which derive from it.

All the considerations contained in this section refer to two fundamental principles: on the one hand, the action of the planets on plants and, on the other hand, the action and the mixing of the four elements (ground, water, air, fire) and of the four natural qualities (dryness, wetness, cold, heat) which derive from them.

## ARABIC AGRICULTURE

From botany to agriculture, the transition is normal. After presentation of the sources common to the two disciplines, the systematic classification of plants and a schematic exposition on phytobiological and morphological problems, let us deal with the second aspect which includes the concept of *filāḥa*, i.e. the culture and care which plants need.

Here also, the *Nabatean Agriculture* seems to be the best testimony for the state of agricultural knowledge at the end of the third/ninth century. The conduct of an agricultural enterprise, as described in this work was adopted by later authors. It is a procedure, however, of which the essentials are described by Greek and Latin agronomists. With the *Nabatean Agriculture* one can consider that the bases for ancient and medieval agronomy are definitively established. An inventory of the contents of this work demonstrates this.[48]

After the first section, dedicated to the olive tree, which opens the book, a long section is devoted to water whose existence conditions agriculture. Eight chapters deal with the following subjects:

1 The research of water and the related technical knowledge[49]
2 How to dig wells and how to increase the flow by proven artifices and techniques
3 The drilling of the wells
4 The artifices used to increase the water in a well
5 How to make the water rise up a very deep well
6 How to augment the quantity of water in wells and sources
7 How to modify the taste of the water and improve it
8 On the difference in nature and action of the water according to its position (more or less) close or far away with regard to the ecliptic[50]

After the third section which deals with aromatic floral plants, and the fourth section which deals with trees and bushes with medicinal properties, there is an important section which can be entitled 'The vade-mecum of the agriculturist'. In this section the following questions are discussed in the main.

1 The management of an agricultural enterprise: duties of the owner regarding his enterprise and the workers.
2 The official in charge (*wakīl*) of the management of the enterprise: his obligations towards the farmers; applying the instructions which he receives from his boss.[51]
3 The forecasting of atmospheric changes; signs picked up from the planetary astral alterations (*Agr. nab.*: I, 209–10).
4 Signs of rain, taken from observation of the lunar crescent, the nature of the thunder and lightning, the direction of sunrise, the behaviour of certain animals and plants. Forecasts from the movement of winds on the 24 November, the great moon festival (*ibid.*, 211–14).
5 How to recognize cultures which succeed in a certain year (*ibid.*, 214–18).
6 The different work and the seasons: a list of work to be done in each month of the year, starting from March.[52]
7 When is the moon on top and underneath the earth (*ibid.*, 241–3)?
8 What a farmer and the owner of an agricultural enterprise must necessarily know: theoretical exposition on the movements of the sun through the signs of the zodiac and the consequent effects for the three kingdoms, animal, vegetable and mineral. The diseases which result from this (trees which do not bear fruit any more, vines overtaken by 'stars' disease' or jaundice) and their treatments. Modification of nature, action and form in plants. The importance of agriculture and farmers for all men and particularly for the powerful. The farmers' opponents (ascetics and anachorites). The author talks with one of them. On their pretensions in obeying the orders of idols (*ibid.*, 244–62).
9 The pollenized air and winds: consequence of the sun's movement through the signs of the zodiac; receptivity of the atmosphere; humidity and dryness; vapours and water. The pollen plants and the corresponding winds; non-pollen plants and favourable winds. Specific action of winds on certain plants. The four cardinal winds and the intermediary winds: detailed exposition about each with indication of the seasons in which it blows and the effects produced, always in relation to the displacement of the sun through the signs of the zodiac. Properties and seasonal and astral variations (*ibid.*, 262–77).
10 Formation of vapours and winds: genesis of the humid vapour and the dry vapour; transformation of the vapours into rain with the help of

winds; different kinds of rain and their respective beneficial or noxious effects on different kinds of plants, from a qualitative and quantitative point of view. Nature of the clouds. Corruption of fruit; corruption of torrential waters (*saylī*) and of diluvian floods (*ṭūfānī*). Treatment of plants suffering from this corruption: different manures described. Noxiousness of vapours and clouds, contracted from plants and the stars (*ibid.*, 277–300).

11 Causes of the corruption of torrential rain and of large and small plants, described exclusively for plants. The 'stars' disease' and its causes; its signs; other diseases (*āfāt funūniyva*) (*ibid.*, 300–7).

12 Nature of soils; their different flavours. Importance of the soil for plants; its noxious flavours and smells. Treatment of each kind of ground. Sulphur and salty ground; variations occurring in the nature of soils and consequently in animals, vegetables and minerals. Dry land and wet land and its consequences on plants. How to recognize good land? Nature of soils and appropriate cultures. Causes of soil corruption, one of them being the burying of corpses. Compact ground and its treatment; heavy and clayey ground; light ground; red, sandy, desert ground; oozing ground; acid ground. Comparison of soil and water in flavour. Wild plants growing on the different soils listed above; all plants have healing qualities. Ashen, carbonized, bitter, clay ground; its treatment. Genesis of all the flavours; example of soils and plants that prosper there. Plants with marvellous properties (*ibid.*, 307–61).

13 The manure. Natural and artificial manure. List of different manures. Human excrement and its multiple properties, on its own or mixed with others. The compost: way of fabrication, use. Effects of the manure on plants and on the soil. Superiority of the columbine (*ibid.*, 361–77).

14 How to get rid of bad herbs (stipes, couch-grass, cuckoo pint, thistles, reeds) and how to cut the plants which need to be cut. To clean a piece of land from these herbs one must develop certain cultures there (*ibid.*, 378–406).

In the sixth section concerning leguminous plants and grains, the author gives the following information (*ibid.*, 406–662).

1 The choice of land for certain grains and seeds; the time for sowing. Conditions for the culture of wheat and other cereals; from sowing to harvest.

2 Culture and prophylaxis of cereals; procedures to obtain grains with good size. Good treatment of the farmers helps the size of the grain. Cold areas are more suited to the culture of cereals. Procedures on how to protect cereals against attack by insects and sky and ground birds.

3 The harvest: preparation of the area; choice of place with regard to the wind. Sluicing. Nuisance of pulverized straw.

4 Storage of wheat and barley: in places where the rising sun can penetrate, protected from the south wind, exposed to fresh air. Procedures on how to preserve them from worms.

5 Signs of corruption in wheat and barley: smell, weight, colour.

6 Wheat and barley bread: the role of grain washing; bran and flour; their medicinal properties; grinding; yield.

7 Quality of the best bread: fermented dough and non-fermented dough; ersatz of the yeast. How to bake the best bread? Qualities of bread baked from a dough kneaded with water 'exposed to the stars' gleam' (*munajjam*); quality of water to use. Storage of the flour. Different kinds of bread.

8 Quality of wheat and barley: signs of good and bad grain; influence of the weather on the quality of the cereals and on human health; healing with air, sport and diet. How to facilitate the digestion of cereals? Their nutritive qualities. Different kinds of bread from cereals, acorns and other vegetable products. Different kinds of wheat and barley. Nutritive and medicinal properties of barley.

9 Bread of wheat and barley: nutritive properties; different condition for baking bread. Medicinal properties. The 'washed' bread, the 'broken' bread (*fatta*); the most digestible bread; qualities of the different kinds of bread; confection of barley infusion.

10 Herbs similar to wheat and barley growing with them: list of these herbs; their grains are bitter; some, like cockle and false rye, are nourishment for birds. The harmfulness of false rye for men; its medicinal properties.

11 At the end of this section, the author lists twenty kinds of bread made from fruit dough: bread from acorns, from chestnuts, mixed with corn, from Syrian carob trees, from spathes and palmites, from pears, from myrtle grains, from grains and leaves of sumac, mulberries, from laurel grains, from quince, from chaenomele, from sweet almonds, from hawthorn, from cherry plums, from figs, from sycamore, from cherries, from acacia grains, from dry grapes, from dried vine leaves. In sum, the author concludes, all edible fruit can be made into bread. One can correct the flavours of the fruits by adding herbs, vegetables, salt, vinegar, etc. One can also bake bread from the kernels of fruits, notably dates and pulpy fruits.

12 As a conclusion to this section the author studies wild plants: their properties, according to seasons and places, the action of the planets on each species through the combination of the four elements. Culinary use of wild plants; how to store them together. Classification into (a) wild trees, (b) wild vegetables and (c) rhizomes of wild plants. These wild

herbs are more medicinal product than a food. Use of thyme, fumitory, the fox grape, hyssop, fennel etc.

Section 8 is dedicated to phytobiology and the morphology of plants. We will find a summary above.

Section 9 is dedicated to vegetables of which seventy-one are studied (*Agr. nab.*: II, 761–914).

A long section is dedicated to the vine. After an introduction, the author studies suitable soils and winds, the way and time of planting, orientation with regard to wind, pruning, the required tending, the diseases which affect it, the theriacale vine (*ibid.*, 915–1132).

Section 11 concerns trees: after an introduction about wild trees, the author studies (a) fruit trees (forty-one) and (b) forest trees (thirty-seven) (*ibid.*, 1132–281).

A long description is dedicated here to grafting but it is difficult to list here all the varieties. The author puts aside the current graft in order to explain some specific grafts that are not very well known, such as grafting a shoot of scammony on a fig tree, on an apple tree; grafting a shoot of sebesten onto an olive tree; grafting a basil tip with three parts of myrrh at the base of an apricot tree, etc. The aim of the operation is to give new properties to the grafted tree or to improve it or to diversify its fruits (*ibid.*, 1281–312).

It is a part full of teaching useful to the agriculturalist. It is difficult to give a complete summary. It is followed by a section, the twelfth, dedicated to the autogenesis of plants and to the art of reproducing or imitating nature, which we have given the title *ars magnus*. It is a section comparable with alchemy from the Jabirian corpus and it is about the *homonculus* identified by a Babylonian magician named ʿAnkabūthā (*ibid.*, 1312–39).

We can summarize this section as follows.

1 Causes of plants which grow spontaneously.
2 Processes of the genesis of plants from the tilling of the ground under the action of water, fire and air.
3 The improvement of the ground by the balance in it of the action of the other elements, making it suited for transmutation; then, from a putrefaction produced in olden times, grains, kernals and seeds are formed.
4 Starting from this principle men have imitated nature's action by producing new plants in artificial generation.
5 There is here proof of the possibility of transmutation between the three kingdoms, in particular the animal and the vegetable.
6 But we need to know how to combine suitable elements for every artificial generation. Numerous examples given allow the practice to be extended to other plants.

Section 13 is dedicated to the date palm; it is a very long section, forming a treatise on its own, like those about the viney and the olive tree. The author speaks about the varieties of date palms, their culture and the tending that they require, of their diseases and treatments, the transfer of the sapling, the superiority of the date palm over other vegetables, the numerous properties of the fruit of the date palm (*ibid.*, 1339–53).

Here, in summary are the theoretical and practical teachings given to the agriculturalist besides those dealing with plants and planting, given in the part dedicated to the classification of plants (see above, p. 821).

For a long time, the *Nabatean Agriculture* remained the only agricultural treatise in the East. It was necessary to wait for the eighth/fourteenth century to find an original work on agriculture: it is the fourth part (*fann*) of the *Kitāb Majāhij al-fikar* of Jamāl al-Dīn Muḥammad b. Yaḥyā al-Waṭwāṭ al-Kutubī (d. 718/1318), where the *Nabatean Agriculture* is extensively used.[53] After it two important texts deserve mention: the first is the *Kitāb bughyat al-fallāḥīn fī al-ashjār al-muthmira wa-l-rayāḥīn* by the Yemenite Sultan al-Malik al-Afḍal al-ʿAbbās b. ʿAlī who reigned from 764/1363 to 778/1376; the second is the *Kitāb ʿalam al-malāḥa fī ʿilm al-falāḥa* which is a compendium written in 1137/1715 by ʿAbd al-Ghanī al-Nābulsī of a great agricultural treatise which had been compiled by the Damascan, Raḍī al-Dīn Abū al-Faḍl Muḥammad al-Ghazzī al-ʿĀmirī (d. 935/1529). It is a compilation of a practical nature which concerns the knowledge of soils, irrigation, the planting of trees, aromatic plants and flowers, size, pruning, pollenization, the improvement of the yield, the grafting of fruit trees, the sympathy, resemblance, antipathy, opposition existing between plants, treatments of their diseases.[54]

It was in Andalusia that the Arabic agronomic literature knew its greatest development. In Seville there was Ibn Ḥajjāj al-Ishbīlī, author of the *Kitāb al-Mughnī fī al-filāḥa*, compiled in 466/1073, which is based on thirteen sources which he enumerates,[55] and Abū Khayr al-Ishbīlī, author of a *Kitāb al-filāḥa*.[56]

The work of Ibn al-Ḥajjāj deserves some attention. This author introduced in Arabic agronomic and botanical science the Latin agronomic tradition represented by Varron (first century BC) and Columella (first century AD), side by side with the Eastern tradition represented by the *Nabatean Agriculture*, well known by the Andalusian *agrimensores*.

In fact at the end of his book (p. 123) Ibn Ḥajjāj claims to have mentioned twenty-three *agrimensores*. The first, whose name is cited twenty-eight times, is called Jūniūs. It is probably Lucius Junius Moderatus Columella, author of an agricultural treatise entitled *De re rustica*.

We have seen above that some authors prefer this identification while Manfred Ullmann says that Yūnīus is a corruption of Vindanionos. I myself am not very convinced by this explanation. Certainly, it is only after a confrontation with the Latin original of the quotations made by Ibn Ḥajjāj that we can settle the matter.

Naturally this assumes that the work of Columella, from Cadix, left traces in the agronomical knowledge of the people in his region of origin, although he lived and worked in Italy. Ibn Ḥajjāj, of the Seville aristocracy, could have known the work of Columella, Latin being then the language in cultured circles, notably among the Jews and Christians, very often demanded by the Muslims. Some similarities allow us to assume this.

The first refers to the fact that the two authors dedicated their books to two characters unknown to us, but probably friends of one and of the other: Columella names his dedicatee P. Silvinus, whilst Ibn Ḥajjāj gives him the qualification *akhī wa-walīyī*, 'my brother and neighbour'. The term *akhī* can have a wide meaning encompassing family relations and the term *walī* can have different meanings like 'neighbour' (that seems to have been the case with Silvinus), 'friend', 'teacher', 'father-in-law'.

The second one appears in the citation, in the introduction, of the names of the ancients who became famous in the art of cultivating the ground. The first two named in the two treatises are Democritus and Pythagoras. Columella gives them as an example for their general knowledge of nature (I, 32); Ibn Ḥajjāj considers them as 'wise men' or 'philosophers' (*ḥukamā'*) 'having written in their agricultural books what they thought had been definitively acquired in this art' (p. 5). Columella follows these two names with a series of other wise men who have enriched the agronomical sciences by their knowledge and experience. Ibn Ḥajjāj summarizes this passage containing proper names which say nothing to his dedicatee by the following phrase: 'and other philosophers who have left us the fruits of their wisdom and the products of their thoughts'.

Ibn Ḥajjāj's treatise was intended to be a collection of the experiences transmitted to us by the ancients in their texts about rural economy. It gives at the end the list of sources which are manifestly Greek and Latin. This list is comparable to that given by Columella in Book I, 6 *et seq.* These names have been distorted by the scribes to such an extent that it is very difficult to establish their identity.

The similarities in terms of knowledge and agricultural practices are numerous. To allow a detailed comparison which will not be out of place here let us indicate the subjects where the name of Jūnīus is mentioned.

He is mentioned on the subject of the pear tree (p. 43), the olive tree (pp. 85–98), pruning (pp. 98–106) and the exposing of the vine roots, the cultures between vine (p. 107), the lightening of the leaves (p. 108), the manure for the vine (p. 109), vegetables (pp. 112–13), the cauliflower, the lettuce, the leek, the radish, the beet (pp. 114–15), the rue, the garlic, the onion (pp. 116–17), the artichoke (p. 120). The citations essentially concern viticulture, arboriculture and horticulture which are the major preoccupations of *De re rustica*.

In Toledo, Ibn Baṣṣāl wrote the *Kitāb al-qaṣd wa-l-bayān*, a compendium from the *Dīwān al-filāḥa* mentioned by Ibn al-ʿAwwām. The work includes sixteen chapters dealing with the kinds of water, the ten kinds of good land, the seven kinds of manure, the signs of a good soil, the culture of fruit trees,[57] etc.

But the most famous Andalusian remains Ibn al-ʿAwwām al-Ishbīlī, author of the *Kitāb al-filāḥa* which synthesizes the agricultural knowledge that he managed to collect from his numerous predecessors, starting with the *Nabatean Agriculture*.

The book comprises thirty chapters about agricultural matters and four chapters on zoology. A resume from the agricultural part allows us to establish the evolution of Arabic agriculture since the *Nabatean Agriculture*.

- In the first chapter the author describes the varieties of ground: black, red, violet, yellow, white, clayey, stony, mountainous, etc. He explains the way to recognize good land and the procedures for improving poor land.
- In the second he talks about manure, its preparation and its use.
- In the third he speaks about water and its use for each sort of plant; the wells and the way to recognize the deepness of the water in relation to the surface of the soil.
- In the fourth he describes the creation of gardens, their planning and the preparation of their plants.
- In the fifth and sixth he deals with plants and the moment for their planting; their transplanting; the way to plant fruit trees, such as the apple tree, the fig tree, the vine, etc.
- In the seventh is considered the planting of the olive tree and of other fruit and forest trees; the culture of the vine, sugar cane, the banana tree, roses, etc.
- In the eighth he explains grafting.
- In the ninth he talks about the size of trees.
- In the tenth he describes agricultural work.
- In the eleventh he speaks about manure.
- In the twelfth he talks about the watering.
- The thirteenth is about the artificial fructification and the enlargement of fruits.
- The fourteenth shows the way to treat plants suffering from diseases.
- The fifteenth explains the way to give aroma to fruit and colour to roses.
- The sixteenth tells how to preserve grains, vegetables, onions, fruit.

In the fourteen chapters which follow, he deals with particular cultures of cereals, vegetables, leguminous plants; the harvest; plants used for fabrics; plants used in dyeing, vegetables, aromatic plants, etc.

The richness of this work is such that it is difficult to summarize the contents. We can find there 585 cultures, of which fifty-five concern fruit trees. It was edited and translated into Spanish by Banqueri in Madrid in 1801–2, and was translated into French by Clement-Mullet in Paris in 1864–7.[58] In addition, it is the best known in Europe of the Arabic *agrimensores*.

With Ibn al-ʿAwwām, who wrote towards the end of the twelfth century, time of prosperity which Arabic agriculture had known in Andalusia drew to a close.

Judging by the double exposition above, the botanical and agricultural knowledge was very rich with the Arabs of the Middle Ages. Their agrotechnical and economic knowledge is demonstrated in the following:

1 in the preliminary knowledge that an agriculturalist was supposed to possess concerning meteorology, climatology, hydrology, the economy and management of agricultural enterprises and everything regarding the concept of soil occupation (*ʿimārat al-arḍ*).
2 in agricultural knowledge proper, i.e. pedology, agricultural ecology, irrigation, preparation of the soil, planting, spreading of the manure, killing the herbs, sowing, the cutting of trees, grafting, the pruning of the vine, prophylaxis, the phytotherapy, all tasks relative to the care and improvement of cultures and plants, the harvest and the storage of crops.

The botanical knowledge is by no means less rich, since in addition to the treatises on plants, treatises on agriculture complete the botanical treatises, by expounding all the knowledge about fruit and forest trees, bushes and aromatic, oleaginous, vegetable, wild, leguminous, cereal plants, etc.

To all this is added a mass of data with a medicinal and culinary character, illustrating the utility of plants. These data could form a kind of treatise in alimentary economy representing the crowning of agricultural activities.

Although the treatises in botany and agriculture which we have presented above constitute the fundamental sources for the history of botany and agriculture, they are not the only ones to be taken into consideration. In effect, botanical and agricultural data can be gleaned on the one hand, in books on finance such as the *Qawānīn al-dawāwīn* of Ibn Mammātī and the financial treatise of al-Makhzūmī[59] and, on the other hand, encyclopaedic works about the whole of nature, such as the chapter entitled *Bāb al-shajar wa al-nabāt* from the *Kitāb ʿUyūn al-akhbār* of Ibn Qutayba (d. 276/889),[60] the *Rasā'il* of Ikhwān al-Ṣafā' (twenty-first *risāla*), the sections on the *ṭabī'iyyāt* in philosophical and medical texts like the *Kitāb al-Shifā'* (section VII) of Ibn Sīnā,[61] the texts with a historical and cosmographic character like the *Kitāb al-I'tibār*[62] of 'Abd al-Laṭīf al-Baghdādī, the *'Ajā'ib al-makhlūqāt*[63] of al-Qazwīnī, the *Nihāyat al-arab* of Shihāb al-Dīn al-Nuwayrī,[64] the *Maṭāli' al-budūr*[65] of al-Juzūlī, the *Kharīdat al-'ajā'ib*[66] of 'Umar b. al-Wardī.[67] It is on the whole a work of compilation which is only interesting in the sense that they use lost texts or they register personal observations about the state of cultures in their respective times.

We cannot write a complete history about Arabic botany and agriculture without studying, appreciating, realizing the value of the data from all these sources. We have limited ourselves here to presenting the basic elements of the history of botany and agriculture.

## NOTES

1 Cf. Fahd (1977).

2 *L'agriculture nabatéenne*. Translation into Arabic attributed to Abū Bakr Aḥmad b. 'Alī al-Kasdānī, known as Ibn Waḥšiyya (4th/10th century). Critical edition by Toufic Fahd, 2 vols (Damascus, 1993 and 1995). For an exposition of the contents of this treatise, see Fahd (1977).

3 Le *Kitāb al-nabāt* does not seem to be by al-Aṣma'ī (cf. Sezgin (1971: IV, pp. 333–4) quoting Silberberg (1910: 258–60)).

4 Ed. Nagelberg (1909).

5 Partly available, cf. Silberberg (1910); it contains about 400 descriptions of plants from the work of al-Dīnawarī.

6 *Khizānat al-adab*, I, p. 11, 1.18.

7 Cf. Lewin (1960: 131–6).

8 Cf. Lewin (1953).

9 *Le Dictionnaire botanique d'Abū Ḥanīfa al-Dīnawarī*, reconstructed from quotations from later works; cf. al-Dīnawarī, *Le Dictionnaire botanique*.

10 Cf. Democritus; the identification is contested by Kroll in *Hermes* 69 (1934: 230). For details see Sezgin (1971: IV, pp. 310–12).

11 Cf. Oder (1890: 58–9).

12 Cf. Lagarde (1855).

13 Collection Rida 5762, 191 folios, dating from 732/1331. Paul Sbath is thought to have discovered this work (cf. *Bulletin de l'Institut d'Egypte* 13 (1930–1), pp. 47–54) but according to Sezgin (1971: IV, p. 315), it seems that it is probably *Kitāb al-Filāḥa*, attributed to Balīnās (Apollonius of Tyana).

14 Cf. Gmoll (1883: 221 *et seq.*).

15 Cf. Ullmann (1972: 433).

16 Cf. Nallino (1922: 346–7).

17 For details see Sezgin (1971: IV, pp. 317 *et seq.*); Ullmann (1972: 433–7).

18 On the argument about the authenticity of this work, see our article *Ibn Waḥshiyya*, *Encyclopédie de l'Islam*, 2nd edn, and on its contents see Fahd (1977).

19 In *Islamica*, 16, pp. 241–81; for details see Ullmann (1972: 71 *et seq.*); Sezgin (1971: IV, pp. 312–13).

20 It also has the title *Kitāb al-ʿilal* (*Book of Causes*). See the Bibliography.

21 English edition and translation by Mingana.

22 On these translations and commentaries see details in Sezgin (1970: III, pp. 58–60) and Dietrich.

23 MS Bursa, Ulucami, *lughat* I, folios 129v–132v, dating from 1127/1715; cf. Ritter (1949: 241–2).

24 Schmuker (1969). The *Firdaws* was edited by Ṣiddīqī. See the Bibliography.

25 Edition from Cairo (1965). On the main themes of this section see Ullmann (1972: 78 *et seq.*).

26 The *Kitāb al-nabāt* was edited and translated into Spanish by Miguel Asín Palacíos; see Ibn Bājja in the Bibliography and Ullmann (1972: 80).

27 It is about the *Kitāb Iʿtimād al-adwiya al-mufrada* on the content of which seen Volger (1941); Sezgin (1970: III, pp. 304 *et seq.*).

28 On this text see Kahle (1952).

29 Cf. Meyerhof (1940: xxvi); Sezgin (1970: III, pp. 323 *et seq.*).

30 Translation printed in Strasbourg in 1531 and in Venice from 1532 and frequently used in the West. From the Arabic text there is a manuscript in the Escurial (no. 833). Cf. Meyerhof (1940: xxvii).

31 Cf. on this subject Meyerhof (1930).

32 Cairo, 1940, LXXVI, 69 pp.

33 Cf. Meyerhof (1940: xxxi *et seq.*).

34 *Voyages d'Ibn Baṭṭūṭa*, see the Bibliography.

35 Cf. Yāqūt, article 'Ṣiqilliyya', quoting a certain Abū ʿAlī.

36 Cf. Ibn Ḥawqal; Michele Amari.

37 See *Agr. nab.*: I, 609. One will find all these data for each of the vegetables described. We shall indicate schematically the main points treated.

38 Variety of acacia. The *ḥulba* designates the fruits of thorny trees (cf. al-Dīnawarī, no. 254).

39 After the cedar, the author mentions the silver cyprus (*sharbīn*), not because it is a fruit tree but because of the tar it produces, just like the male pine tree named in the preceding rubric. For the medicinal properties of this tar, see Ibn Bayṭār, III, pp. 60–2.

40 The author of the *Nabatean Agriculture* gives eight more names of trees in this category with an aramaic analogy, which I was not able to identify.

41 The *ballūṭ* designates the oak with galls (*ʿafṣ*: al-Dīnawarī, no. 728) whose acorns are edible, although the *sindyān* designates the oak rouvre. The author gives here three names of trees growing in Babylonia which we were not able to identify.

42 Three names of unidentified trees are missing from this list.

43 Several names of plants in this list are still not identified; these plants seem to be from Babylonia. Here is placed a long exposition about the numerous varieties of breads that one can bake from plants, herbs, roots and acorns. Eighteen varieties are described (see *Agr. nab.*: I, 638 ff).

44 This section should be compared with Book IV of the *Kitāb sirr al-khalīqa wa-ṣanʿat al-ṭabīʿa* (or *Kitāb al-ʿilal*) of Pseudo-Apollonius of Tyana, pp. 309–91, where the origin of plants and their morphology is analysed.
45 On the contents of this chapter see Fahd (1976).
46 Cf. Fahd (1973).
47 Cf. Fahd (1974b).
48 For a detailed description of the book see Fahd (1977).
49 *Agr. nab.*: I, 54–111.
50 Cf. a detailed analysis of this section in Fahd (1971).
51 Cf. *Agr. nab.*: I, 194–209. A detailed exposition of the contents of this section is in Fahd (1970).
52 See *Agr. nab.*: I, 218–41. Cf. the contents of this long chapter in Fahd (1974a).
53 On the contents of this part, cf. Ullmann (1972: 448–9).
54 More details on the contents of this work can be found in Ullmann (1972: 450 *et seq.*). There is a Damascan edition from 1299/1882.
55 Edited in Amman in 1982.
56 Jose M. Millas Vallicrosa dedicated a study to it (1955). Cf. details in Ullmann (1972: 444, 446).
57 Cf. Ibn Baṣṣāl, in the Bibliography.
58 For more details, see Ullmann (1972: 447–8).
59 Cf. Cahen (1971).
60 *Uyūn*, II, pp. 106 *et seq.*, of which one part has been translated into German by Wiedmann (1915: 116–18).
61 Cf. Asín Palacios (1940).
62 Ch. 2, pp. 30–79; translation by Sacy, pp. 16–134.
63 Cf. Wiedmann (1912, 1916b).
64 Vol. XI, pp. 1–330; cf. Wiedmann (1916c).
65 Vol. I, pp. 93–113.
66 Pp. 174–97.
67 For more details see Ullmann (1972: 77 *et seq.*).

# 25

# *Arabic alchemy*

GEORGES C. ANAWATI

Following the work of French chemist Marcellin Berthelot[1] on alchemy many researchers, on the basis of original texts discovered and published, became interested in the study of alchemy with the Arabs: Lippmann, Wiedemann, Ganzenmüller, Stapleton, Holmyard, Plessner and especially Paul Kraus whose work about Jābir ibn Ḥayyān is still a classic in this subject. More recently Henry Corbin in his research on Shiʿism has tried to give an esoteric interpretation of the great alchemy texts. His ideas created a school of thought and some contemporary authors, Roger Deladrière and Pierre Lory for instance, did not escape his influence. Arabic alchemy is no longer the 'terra incognita' which, a century ago, challenged the insight of historians of science.

The large quantity of accumulated facts suggested a synthetic presentation to Fuat Sezgin and Manfred Ullmann. The former produced his in the frame of his series *Geschichte des arabischen Schrifttums*; the fourth volume, appearing in 1971, dedicated several pages to alchemy. In his turn, Ullmann, in his book *Die Natur- und Geheimwissenschaften in Islam*, appearing in 1972, presented in about a hundred pages the whole of Arabic alchemic literature studying successively the translations and pseudo-epigraphs from Greek authors, Egyptian, Indian, Persian, Jewish and Christian sources, then alchemy theories, the research of the elixir, laboratory experiments and the material employed, and the whole is copiously documented.

In this short chapter we cannot treat the history of alchemy in all its breadth. We are obliged to stick to essentials. The plan we shall follow is this. In the first part we shall study the old sources which were known and used by Arab alchemists. They are first and foremost Greek authors, through their Arabic translations, and then Egyptian, Indian, Jewish and Christian sources. We shall try to characterize the nature of the Hellenistic and Byzantine contribution.

The second part, chronological, will be dedicated to the Arab alchemists themselves, concentrating on two important characters, Jābir ibn Ḥayyān and Abū Bakr al-Rāzī, the Rhazes of the medieval West. Finally in the third part we shall explain, in some detail, the judgement on alchemy made by two important Arab thinkers; Avicenna and Ibn Khaldūn.

### Etymology[2]

The word 'alchemy', as the article *al-* indicates, is Arabic (*al-kīmyā'*). The origin of the word *kīmyā'*, pre-Arabic, is arguable. Several more or less plausible or legendary hypotheses have been advanced. For some the word came from the Egyptian *kemi* (black), whence the Greek *kemia* which might indicate two things:

1 Egypt, 'the black land' according to Plutarch – alchemy would be pre-eminently the science of Egypt;
2 'the Black', the original matter of transmutation, i.e. the art of treating 'black metal' to produce precious metals.

For others, the word 'chemy' could have come from the Greek *khymeia*, 'fusion', i.e. the art of melting gold and silver. A Byzantine text (*Le Souda*) states that Diocletian ordered the destruction of Egyptian books relating to *khymeia*, to the 'fusion' of gold and silver.

## THE SOURCES OF ALCHEMY AMONG THE ARABS

### Pythagoras (Fīthāghūrus)

Pythagoras is often mentioned in Arabic philosophy and in gnomic literature. Jaldakī calls him *al-muʿallim al-awwal* because he acquired the science from hermetic texts. Jābir refers to him as an alchemic author and speaks of *Ṭā'ifat Fīthāghūrus*, the school of Pythagoras, and of his book *Kitāb al-muṣaḥḥaḥāt* (*Book of Adjustments*). Other quotations refer to Pythagoras's theory of numbers. Ṭughrā'ī mentions him several times and refers to his treatise about 'natural numbers'. The fragments of texts which are attributed to him could have come either from *Turba philosophorum*, where he is among the participants, or from other texts.[3]

### Archelaos

Archelaos is mentioned in the *Fihrist* (p. 352, 25) and by al-Kindī in his *Faḍā'il Miṣr* (p. 191, 11). He is considered as the disciple of Anaxagoras and the teacher of Socrates. He should not be confused with his Byzantine namesake, author of an alchemic poem of 336 verses.[4]

The Arabs consider him as the author of *Turba philosophorum* (*Muṣḥaf* *al-jamāʿa*) and attribute to him the *Risālat madd al-baḥr dhāt al-ruʾya*, a text which had been revealed in a vision about the tide[5] and which was translated into Latin with the title *Visio Arislei*. This text is introduced as the continuation of *Turba philosophorum*.

### Socrates[6]

Socrates is considered not only as a wise man but also as an alchemist. Jābir calls him 'the father and mother of all philosophers' and considers him as the prototype of the real chemist. From Socrates to Jābir, there is a continuous tradition which attributes entire treatises to him. Jābir affirms that Socrates was opposed to the writing down of alchemic knowledge to avoid its exposition to the ignorance of the masses. Most references to Socrates refer to his arithmetical speculations (theory of the balance) and also to artificial generation.

### Plato (Aflāṭūn)[7]

Olympiodorus already (at the end of the sixth century) considered Plato as an alchemist and Ibn al-Nadīm mentions him in the list of alchemists. Buṭrus al-Ilmīmī mentions an alchemic device called *ḥammām Aflāṭūn* (Plato's bath).

Among the books attributed to him by the Arabs we can mention the *Summa Platonis* of which we only have the Latin version. There is a commentary to this book – the *Kitāb al-Rawābīʿ* – whose Arabic text was edited by Badawī and whose Latin translation is known by the name *Liber quartorum*.[8] The contents of this work are mainly alchemic but it contains also information on geometry, physiology and astrology. The ancient authors cited are Plato, Aristotle, Ptolemy, Hipparchus, Proclus, the Sophists, Ostanes, Hermes, Asclepius and Hippocrates.

We note also that Plato takes up the story in the forty-fifth discourse in *Turba philosophorum*; this speech ends with the phrase *al-ṭabīʿa tulzimu-l-ṭabīʿata wa-l-ṭabīʿatu taqharu-l-ṭabīʿata wa-l-ṭabīʿata tafraḥu li-l-ṭabīʿati* (nature necessarily accompanies nature, nature overcomes nature, nature rejoices in nature), an aphorism often mentioned in Arabic alchemic literature under the name of Plato or anonymously. It comes from the *Physika kai Mystika* of Democritus.

### Aristotle (Arisṭū)[9]

Aristotle is considered as an alchemist author not so much because of his fourth book *Meteorologica* but because of his reputation as an all-round scholar. He wrote a book on alchemy for his disciple Alexander. In 618, by order of Heraclius, the book was translated into Syriac by the monk Jean, and the Bishop of Nisibis, Eliyya bar Shināya, made sure of its orthodoxy. Finally Abdīshū' bar Brīka, Bishop of Sinjar, and later of Nisibis, made a commentary on it in Syriac of which there still exists an Arabic translation.[10] The text contains an introduction in which Abdīshū' reports the legendary history of the text followed by a letter from Alexander to Aristotle where the former poses questions to which the latter responds. This dialogue is called *Ṣaḥīfat kanz Allāh al-akbar* (*Epistle of the Great Treasure of God*). It includes three chapters: (1) About the great principles of alchemy; (2) Alchemic operations; (3) The elixir. Pythagoras, Democritus, Asclepiades, Hermes, Plato, Ostanes and Balīnās are mentioned in the text.

We also have a dialogue between Aristotle and the Indian Yūhīn sent by the Indian king as messenger to Alexander. Ibn al-Nadīm reports this dialogue to Ostanes. Finally in the Jabirian corpus there is a *Kitāb Muṣaḥḥaḥāt Arisṭūṭālīs*.[11]

### Porphyry (d. *c.* 303)

Porphyry is often mentioned, especially by Jābir who attributes artificial generation to him.[12] The later alchemists such as Ṭughrā'ī and Jaldakī also mention him.

### Galen (Jālīnūs) (d. *c.* 199 AD)[13]

According to a note in *Kitāb al-ḥajar 'alā ra'y Balīnās*, Galen was interested in alchemy before dedicating himself to philosophy. In fact, he is sometimes mentioned as an authority on alchemy[14] and fragments of alchemy texts attributed to Galen can be found in the National Library of Cairo.

### Bolos the Democritean of Mendes[15]

Bolos the Democritean lived in the second century before Christ. The work of this scholar is varied: alchemy, astrology, medicine. He is probably at the origin of the alchemic tradition transmitted by the work of pseudo-Democritus: *Physika kai Mystika*. He expounds there the four traditional branches of alchemy: gold, silver, precious stones, dyes. One can find the famous formula which aims to synthesize the quintessence of the alchemic art: 'one nature is charmed by another nature, one nature overcomes another nature, one nature dominates another nature'.

How can this axiom be explained in practical terms? Zosimus, commentator of the fourth century, explains:[16] 'we can proceed with the transmutation of common metal into noble metal by working alloys or by purifying the metals, basing ourselves on the affinity between metals, knowing their "sympathies and antipathies". Raw material, sympathy, transmutation by qualitative change (of the colours), we have thus the principles that constitute alchemy.'[17] Thus the school of Bolos brings to the Egyptian technique a philosophical reasoning which will open the way to the science of the Great Work. 'Once again', says Festugière,

> we see the union of the Greek spirit and the Oriental art. The art exists, from ancient times; the goldsmiths of Egypt work metals, stones and purple. But although they have innumerable recipes transmitted from father to son and kept in temple archives, they lack a reasoning method. No-one has yet joined these practices with the principles which explain and justify them. There is practice but not theory. This is what the Greek spirit provides. The merit of Bolos of Mendes was to join theory and experiment and thus found a pseudo-science which would cross the ages up to modern chemistry.[18]

About the same time alchemy was practised in most Egyptian towns. This first alchemy is a mixture of hermetic or gnostic elements and old Greek philosophy: Heraclitus, Empedocles and their speculations about the four elements, Parmenides with his theory on the unity of the whole, the Platonic cosmogony of *Timaeus*.

## Zosimus[19]

The most famous character of this time is Zosimus of Panopolis (Akhmīm, in Upper Egypt). He probably lived at the end of the third and beginning of the fourth century; he wrote an encyclopaedia with twenty-eight books on alchemy which he dedicated to his sister Theosebeia. Some sections are original but most of it reproduces old texts lost to the present time. His name in Arabic, because of the ambiguity of the writing, is often transcribed under different forms: Rīsimus, Rūsim, Rūsam. Al-Qifṭī affirms that he lived before Islam.

Some of his aphorisms and anecdotes are reported by Arab authors such as Jāḥiẓ, Ibn Durayd, al-Tawḥīdī. Ibn Arfaʿ Ra's calls him 'the universal wise man and the brilliant flame' (*al-ḥakīm al-jāmiʿ wa-l-shihāb al-lāmiʿ*). Ibn al-Nadīm mentions four books from Zosimus: *Kitāb al-mafātīḥ fī-l-ṣanʿa*; *Kitāb al-sabʿūna risāla*; *Kitāb al-ʿanāṣir*; *Kitāb ilā jāmiʿ al-ḥukamāʾ fī-l-ṣanʿa*.

The epistle from Zosimus to Theosebeia has the title *Muṣḥaf al-ṣuwar* (*The Book of Images*). The name of Theosebeia is often rendered as Atusābiya, Amtūthasiya, Uthāsiya, etc.

Zosimus can be placed at the end of an evolution in alchemy. With Bolos, it became philosophical; with Zosimus it becomes a mystical religion where the idea of salvation is predominant. In fact, the period which separates Bolos the Democritean from Zosimus saw intense alchemic activity. Vastly different elements – Egyptian magic, Greek philosophy, neo-Platonism, Babylonian astrology, Christian theology, pagan mythology – can be found in Zosimus's texts.[20] He is full of gnostic and hermetic books, he knows the Jewish speculations about the Old Testament. He gives to alchemy a religious character which will remain forever, at least in its traditional course, since with the Arab alchemists it will retain its concrete technical character before meeting the Ismaeli gnostic speculations.

Zosimus and his contemporaries who collected their predecessors' traditions insist on their connection with the Egypt of the Pharaohs or with the Persia of Zoroastra and Ostanes. We can find texts under the name of Agathodaimon compared with Hermes. Some written pieces even say that alchemic texts were engraved in hieroglyphs on steles but it was absolutely forbidden to divulge them.

This Greek–Egyptian alchemy survived in Alexandria for several centuries. From here it will go to Constantinople, where several recensions of the 'collection of Greek alchemists' were compiled, and to the Arabs when they conquered Egypt in the seventh century.[21]

### Hermes and Hermetic literature[22]

According to Ibn al-Nadīm (351, 19) Arab alchemists considered the Babylonian Hermes as the first one to have mentioned the art of alchemy. Exiled by his countrymen, he came to Egypt where he became king. He wrote a certain number of books on alchemy and was equally interested in the study of the hidden forces of nature.

The *Fihrist* gives a list of thirteen books of Hermes about alchemy[23] but in fact some of them are about magic. Other texts have been traced: *Al-falakiyya al-kubrā* (*The Great Epistle of the Celestial Spheres*) by Hermes of Denderah; *Risālat al-sirr*; *Kitāb Hirmis ilā Tāt fī-l-ṣanʿa*; *Risālat ḥarb al-kawākib al-barbawiyya*; *Tadbīr Hirmis al-Harāmisa*; *Ṣaḥīfat Hirmis al-ʿuẓma*, commentated by Jaldakī; *Risālat Qabas al-qābis fī tadbīr Hirmis al-Harāmisa*.

### *Sirr al-Khalīqa* of Balīnās[24]

The *Kitāb Sirr al-khalīqa wa ṣanʿat al-ṭabīʿa* also has the title *Kitāb al-ʿilal* (*The Book of Causes*); it was sometimes called simply *Kitāb al-jāmiʿ li-l-ashyā*ʾ. In the introduction a certain Sājiyus is introduced, a priest from

Nablus who commented on the stories of Balīnās. The latter would have found the text at the same time as the *Tabula* in an underground vault in Tyana, under a statue of Hermes. The commentator sketches a cosmology which encompasses the whole universe from the celestial spheres to the least of the minerals, vegetables, animals and man. For each phenomenon he wants to find the cause, whence the title *Kitāb al-ʿilal*.

The author probably lived at the same time as al-Ma'mūn (813–33), as al-Rāzī had already mentioned. Among the sources of the book we can find elements of the *Book on the Nature of Man*, by the Christian neo-Platonist Nemesius of Emesa. However, recent works tend to place this work in a more ancient time. The last chapter of the book from Balīnās is very well known under the name *Tabula Smaragdina* which we shall study later.

There is a second alchemic book from Balīnās entitled *Kitāb al-aṣnām al-sabʿa* (*The Book of the Seven Idols*) known through Jaldakī who mentions and comments on it in his voluminous book *al-Burhān*. It is an alchemic allegory on the metals which is also presented as a revelation. Another alchemic book from him is entitled *Kitāb al-qamar al-akbar*.

### The *Tabula Smaragdina*[25]

One of the most ancient and important documents very much valued by the alchemists and often commented on is the *Emerald Table*, known by the title of the Latin translation, *Tabula Smaragdina*. It is considered as containing the dogma of alchemic work and is attributed to Hermes or to the Egyptian god Toth. The alchemists give it a fabulous origin. The *Tabula* was engraved on an emerald by Hermes himself and was found in his tomb. It was very well known at the beginning of the Latin Middle Ages in at least two Latin versions. But its Arabic origin was proved first by Holmyard and then by Ruska.

Here is what we can understand from this mysterious text: there is a correspondence and a certain interaction between the celestial world and the earthly world; all the manifestations of matter have the same origin; a soul or a universal spirit traverses the microcosm and the macrocosm; the sun and the moon probably represent gold and silver, although later some alchemists tried to see there, in this context, sulphur and mercury.

### Agathodaimon[26]

Etymologically this name means the 'good genie' who protects from evil which threatens persons or homes. It comes to designate the god-serpent and, with the foundation of Alexandria, the reputation of a god that reveals himself, a god of spirits and finally the god of the world.

He enjoys a place of choice amongst the alchemists, but the characteristics of his physiognomy remain uncertain. Olympiodorus in his commentary on Zosimus identifies him with *drakōn Ouraboros*, or an ancient Egyptian philosopher, an angel or the sky. Two alchemic treatises in Greek are attributed to him.

In Arabic we find his name under different forms: Aghāthādhimūn, Aghāthūdhimūn, often shortened to Aghādhīmun. It is under the last form that he is mentioned in Latin in *Turba philosophorum*. The information about him is contradictory. Al-Kindī says that Agathodaimon and Pythagoras are disciples of Hermes while Mubashshir and al-Qifṭī consider the first one as the teacher of Hermes. Ibn Abī Uṣaybīʿa makes him teacher of Asclepius. Al-Masʿūdī reports that the two large pyramids are the tombs of Hermes and Agathodaimon and that the latter lived a thousand years before Hermes. The Sabeens of Ḥarrān considered him, as well as Hermes, Homer and Aratos, as a prophet.

A small treatise, *Risālat al-ḥadhar* (*Epistle of Warning*), was discovered in India, attributed to Aghathodaimon 'the Sabeen, prophet and teacher'. Stapleton has analysed it and translated some extracts. Agathodaimon's text was known by Zosimus who quotes some fragments. In this treatise the author declares that he based it on Hermes' principles taken from his 'books', in particular the aphorism 'the stone is a stone and is not a stone'. This 'Noble Stone' or 'Elixir' derives from 'One thing' (i.e. the Whole which is at the same time God and what God has created) and that seems to be regarded by the Harranians as the essential nature (*kiyān*) of all the mineral substances and metals. The treatise gives practical details for the obtaining of this 'Stone' of which it describes the properties and different phases of the alchemic operation with the succession of colours which appear: red, yellow, white, black and green. Finally the 'Royal colour' appears, the wonderful *Farfīr* (purple), a sign that the philosophical Stone is obtained. A small quantity is enough to transmute any quantity of matter into gold.

We find numerous fragments of Agathodaimon's teaching in the work of later alchemists: *Kitāb al-Ḥabīb*, *Muṣḥaf al-ḥayāt*, in the *Ḥaqā'iq* from Ṭughrā'ī and with Jaldakī.

### Artephius[27]

To the hermetic literature also belong the texts of an author whose Arabic name could not be identified and who in the Latin version has the name Artephius; attempts have been made to identify him with al-Ṭughrā'ī or Ibn Umayl but unsuccessfully. A book entitled *Miftāḥ al-ḥikma* (*The Key of Wisdom*) is known in Latin translation: *Clavis (majoris) sapientiae.*

Artephius is presumed to have been the student of Balīnās. The text is closely related to the *Kitāb Sirr al-khalīqa* of Balīnās.[28]

### *Kitāb al-Ḥabīb*[29]

The *Kitāb al-Ḥabīb* is presented in the form of a testament from the author to his son to console him and to encourage him, and then as a dialogue between a man and a woman, in fact between Zosimus and Theosobeia. The terminology shows a Greek background. The text probably goes back to the period of the *Turba philosophorum*. Democritus is often quoted as well as Pythagoras, Plato, Aristotle, Archelaos, Gregorios, Theophilos, King Aras, Hermes, Agathodaimon and Ostanes.

### Cleopatra[30]

Cleopatra is mentioned by the Greek alchemists often in texts; sketches of devices and symbols are attributed to her in the *Codex Narcianus*. The *Risāla* (in Arabic: *Risāla Qalubātrā malika Samannūd*) is presented in the form of a dialogue; it is not the translation of a Greek text. Jaldakī mentions it in the second part of his *Kitāb al-shams al-akbar*. The terminology indicates Greek sources.

### Maria[31]

Maria plays an important role in alchemy. Jewish gnostic circles see her as the sister of Moses; she herself affirms that she is Jewish. Later legends associated her with the Virgin Mary, mother of Jesus, who plays an important role in the gnostic gospels.

In Islam she is confused with Maria the Copte, the slave offered by the Muqawqas of Alexandria to Muḥammad and who would give him a son Ibrāhīm. Jaldakī refers to other traditions and speaks of her as Maria the Jew, sister of the king of Saba. She is mentioned by Khalīd ibn Yazīd, Ibn al-Nadīm, al-Masʿūdī, al-Kindī and al-Tujībī. The *Risālat al-tāj wa khilqat al-mawlūd* (*Epistle of the Crown and the Creation of the Newly-born Child*) represents, in the form of an allegory of a mother who bears seven children, the formation of seven metals and the possibility of the transformation of metals.

There is a dialogue between Maria and Aras (*Risālat Mariya bint Sāba al-malik al-Qibṭī ilā Aras*, translated into Latin with the title *Practica Mariae prophetissae sororis Moysi*) in which is discussed the problem of the whitening of the stone in a few days. In a *risāla* from Jābir (*Ustuquss* *al-uss*), Maria the Egyptian is mentioned carrying on her back the baby Jesus and in her hand a spindle.

### Ostanes[32]

Ostanes was known in Antiquity as the author of books on magic and gnosis, Ibn al-Nadīm mentions him as a famous alchemist, originally from Alexandria. According to his own testimony, he wrote a thousand brochures and fragments and he uses symbols (*rumūz*) and myths (*alghāz*). *Kitāb al-Fuṣūl al-ithnay ʿashar fī ʿilm al-ḥajar al-mukarram* (*Book of the Twelve Chapters on the Science of the Honourable Stone*) is attributed to him. The book contains three parts: (1) a description of the stone, the breaking up of substances used by the alchemist; (2) trees, natures, spirits, salts; (3) stones, weights, experiments, symbols. Another of his texts is *Muṣḥaf al-ḥakīm Ustānis fī-l-ṣināʿat al-ilāhiyya*.

In a dream he sees an animal trying to eat him: it has the wings of an eagle and the head of an elephant which gives him the keys of the seven doors of wisdom. He finds behind a door a table with inscriptions in seven languages. The first, in Egyptian, contains an allegory about body–spirit–soul; in the second, a Persian text celebrates the wisdom of the Persians; the third attributes the excellence of Indian people to their proximity to the sun; the four last inscriptions are erased. Ostanes is mentioned several times in the *Turba philosophorum*.

### Other non-Greek authors[33]

Some non-Greek names appear in some manuscripts: Mani is mentioned as an alchemist in the *Firdaws al-Ḥikma* of pseudo-Khālid, the brahman Biyūn and a series of alchemists starting with Adam, Seth, Moses, Korah (Qārūn), David, Ezechiel, Jesus, Matthew. As Byzantine authors we find Heraclius (610–41), mentioned in the *Fihrist* (*Kitāb Hirakl al-akbar*), a dialogue between Aras and Theodorus, between Aras and Maria; Theophilos and Gregorios are mentioned in the *Turba*. The monk Marianos according to the legend would be the one who taught Byzantine alchemy to Khālid ibn Yazīd and through him to the Arabs.

Which are the characteristics of this Egyptian–Greek–Byzantine alchemy? It is obviously connected with its sources, and it is often not at all clear. Festugière has characterized the three steps of alchemy amongst the Greeks: alchemy as art, alchemy as philosophy, alchemy as religion.[34] It is Bolos the Democritean who dressed it with the coat of philosophy and it is through Zosimus that it became a mystic religion keeping its connections with chemical technique. Byzantine alchemy follows the latter line. We could describe its main characteristics as follows.[35]

1 Belief in a universal sympathy which intimately unites all parts of the universe: metals and stones are alive, males and females. They suffer the influences of the planets, themselves alive but who can in their turn neutralize this influence – whence the innumerable engraved stones called 'gnostics'. This hidden unity extends also to man, a microcosm inserted in the vast macrocosm.
2 Unity of matter: metals, precious stones can only be distinguished, all things considered, by their exterior qualities, especially colour. To change the colour is to change the metal. To prepare silver and gold one should start from a metal close to the primary purity, then burn and sublimate it.
3 In order to shield alchemic operations from the uninitiated, they should be carried out in deepest secrecy. Secret alphabets, symbolic signs are used; allegories are employed, and explanations regarding one aspect of the doctrine are dispersed into multiple texts.
4 Synthetic formulae are employed unifying in mystery the quintessence of the alchemic doctrine, for instance: 'one nature is charmed by a nature; one nature overcomes another nature; one nature dominates another nature'.
5 The use of special symbols: the *ouroboros*, a serpent which bites itself in the tail, and the philosophical egg to represent the unity and continuity of the whole.
6 The great alchemic operations comprise four fundamental stages: blackening, whitening, yellowing and finally iosis, i.e. becoming violet or oxidized.

The bodies employed, the functions they play in the alchemic operation receive conventional names from the *ouroboros* or the philosophical egg. Finally some alchemic operations are interpreted spiritually: birth, marriage, death, sacrificial offerings, etc.

## ARAB ALCHEMISTS

The Arabs appeared in this history in the seventh century. Alchemy had by then gone through a long path as we have seen in the preceding section. The first contacts took place in Egypt, in Alexandria, where the traditions went back several centuries before Christianity.

### Khālid ibn Yazīd[36]

The first Arab character to be interested in alchemy, according to Ibn al-Nadīm in his *Fihrist*, was the Prince Umayyad Khālid ibn Yazīd, who died around 704. Infatuated with science, he was particularly interested in alchemy. He ordered the translation of some alchemic works from Greek and Coptic, and this was the first time, adds Ibn al-Nadīm, that translations were made in Islam.

Khālid learned alchemy in Alexandria under the supervision of a certain Marianos or Morienos, who himself had been the disciple of the Alexandrian alchemist Stephanos.

Ibn al-Nadīm attributes to Khālid, besides his poem, the following works: *Kitāb al-kharazāt* (*The Book of Pearls*); *Kitāb al-ṣaḥīfa al-kabīr* (*The Big Book of the Roll*); *Kitāb al-ṣaḥīfa al-saghīr* (*The Small Book of the Roll*); *Kitāb Waṣiyyatihi ilā bnihi fī-l-ṣanʿa* (*The Book of his Testament to his Son about Alchemy*). According to the historiographer Ḥajji Khalīfa, the most famous work of Khālid is *Firdaws al-ḥikma* (*The Paradise of Wisdom*) which comprises 2315 verses.

### Jaʿfar al-Ṣādiq (d. 148/765)[37]

Jaʿfar al-Ṣādiq is the son of the Imām Muḥammad al-Bāqir, who was born around 80/700 and died around 148/765. He lived in Medina and was recognized as an authority on the *ḥadīth*. According to Arabic sources, he was the teacher of Jābir. An abundant pseudo-epigraphic literature has been attributed to him, including *waṣāyā* (parenetic advices) and books on the Qur'an verses used as amulets and in geomancy. Six titles are mentioned by Sezgin[38] as alchemic texts. Jaldakī points out an alchemic poem attributed to him.

### Dhū al-Nūn al-Miṣrī (d. 246/861)[39]

Already in the tenth century Dhū al-Nūn is an authority in alchemy. Ibn al-Nadīm mentions two of his works: *Kitāb al-rukn al-akbar* (*The Book of the Great Principle*) and *Kitāb al-thiqa fī-l-ṣināʿa* (*What is Certain about the Alchemic Art*). Ibn Umayl quotes several of his judgements and fragments of his poetry. Dhū al-Nūn is famous for this verse: *ʿajabun ʿajabun ʿajabun* * *Qiṭṭatun sawdā wa lahā dhanabun* (Strange, strange, strange, a black cat which has a tail).

### Jābir ibn Ḥayyān[40]

Since the work of Paul Kraus we are on more solid ground with Jābir ibn Ḥayyān. Born in Ṭūs around 721 or 722 he is also called al-Ṣūfī. Fatherless, he was sent to Arabia where he studied the Qur'an, mathematics and other sciences, coming back to Kūfa afterwards. His figure clearly emerges when he settles down as an alchemist in the court of Hārūn al-Rashīd and becomes a personal friend of the sixth Shiʿite Imām Jaʿfar al-Ṣādiq (700–65) who he always considered as his teacher.

He was also in favour with the Barmecides. Jaʿfar the Barmecide put him in contact with the Caliph for whom he wrote the *Book of Venus* (*Kitāb al-Zahra*) where he describes elegant experiments. He had a laboratory in Kūfa, found two centuries after his death in the neighbourhood of the Door of Damascus. A mortar in gold weighing $2\frac{1}{2}$ pounds was found there.

In 803, Jābir was embroiled in the Barmecides scandal. He got back to Kūfa where he stayed for the rest of his life in seclusion. According to some authors he died in Ṭūs in 815 having under his pillow his manuscript of *The Book of Mercy* (*Kitāb al-Raḥma*).

There is an enormous Jabirian corpus. Kraus has shown that a great part of these works were written at a later date by a group of Ismaelis and it is difficult to determine what belongs to Jābir himself.

The most important groups are as follows:

1 *The Hundred and Twelve Books*, a work dedicated to the Barmecides based on the *Emerald Table*;
2 *The Seventy Books*, work to a great extent translated into Latin in the Middle Ages;
3 *The Ten Books of Adjustment*, where he describes the progress made by alchemists including Pythagoras, Socrates, Plato, etc.;
4 *The Books of Balances*, where he expounds his fundamental theory.

Jābir admits the Aristotelian theory about the composition of matter – earth, water, air, fire – but he develops it along a different path. First, there are four elementary qualities, or natures: heat, cold, dryness, humidity. When they get together with a substance they form compounds of the first degree, i.e. hot, cold, dry, wet. The union of two of these qualities gives

$$\begin{aligned}&\text{hot} + \text{dry} + \text{substance} \rightarrow \text{fire}\\&\text{hot} + \text{wet} + \text{substance} \rightarrow \text{air}\\&\text{cold} + \text{wet} + \text{substance} \rightarrow \text{water}\\&\text{cold} + \text{dry} + \text{substance} \rightarrow \text{earth}\end{aligned}$$

With the metals two of the natures are external and two internal. For instance lead is cold and dry externally and hot and wet internally. Gold is hot and wet externally, cold and dry internally. The sources of these natures are sulphur and mercury, not ordinary sulphur and mercury but hypothetical substances of which the two last represent the closest form.

Sulphur gives hot and dry 'natures': mercury, cold and wet. Under the influences of the planets, metals are formed in the heart of the earth by the union of sulphur and mercury, a theory which will become common and which will last until the appearance of the theory on the combustion of phlogiston in the seventeenth century.

When sulphur and mercury are totally pure and are mixed in a perfect balance, they give the most perfect of the metals: gold. Defects in purity, especially in the proportions, give other metals: silver, lead, tin, iron, copper. But since the constitutive elements are the same, we can try to eliminate this impurity and recover the balance. We achieve this through 'elixirs'.

However, to carry out empirical experiments in this area is just a waste of time; there is weight and size and order in nature. Jābir elaborates on this subject his theory of the balance. It concerns not an equality of mass, of weight, but a balancing of 'natures'. Kraus and Stapleton have studied Jābir's theory and have summarized the main traits. Jābir attaches great importance to the following series of numbers: 1, 3, 5, 8 and 28. The sum of the first four is 17. Everything in the world, according to Jābir, is governed by this number. The metals for instance have 17 powers. The four numbers which compose the number 17 (1, 3, 5 and 8) are part of the following magic square:

| | | |
|---|---|---|
| 4 | 9 | 2 |
| 3 | 5 | 7 |
| 8 | 1 | 6 |

The total is 15 but the gnomomic analysis of the square allows us to find the interesting series. It is certainly the source of Jābir's theory.

Each of the four elementary qualities, or 'natures', comprises for Jābir four degrees and seven subdivisions giving a total of $4 \times 7 = 28$ positions. The number of letters in the Arabic alphabet – 28 – is connected with the subdivisions of heat, cold, dryness and wetness.

According to Jābir there are different elixirs for specific transformations but there also exists one 'great elixir' capable of making all the transmutations, itself having two degrees.

The Harranians and the Alexandrians used mainly, though not exclusively, mineral substances for the preparation of their elixir. Jābir innovates and introduces the use of animal and vegetable products in the alchemic arsenal: marrow, blood, hair, bones, urine of lion or of domestic or wild gazelle, aconite, olives, jasmine, onion, pepper, mustard and anemone. Jābir was not just a theorist but knew perfectly the laboratory manipulations and gave very clear indications for the fabrication of some products (for instance the fabrication of the white lead).[41]

His description of laboratory apparatus and his division of chemical products is less systematic than that of his successors, in particular al-Rāzī. Minerals are divided into three groups.

1 The spirits volatilize when warmed up: sulphur, arsenic (realgar, orpiment), mercury, camphor, sal ammoniac.
2 The metals are melting substances; malleable, resonant, having a lustre. There are seven (gold, silver, lead, tin, copper, iron, *khar-sīnī*).
3 Non-malleable substances, either melting or not, capable of being reduced to powder, can be divided into eight groups according to whether they are stones or not, pulverizable or not, melting or not.

### Abū Bakr al-Rāzī[42]

With Abū Bakr al-Rāzī, the Rhazes of the Latin Middle Ages, we are at the summit of Arabic alchemic science or more exactly chemistry. Al-Rāzī is mainly known as a doctor: his reputation as a physician has drawn the admiration of those who could closely study his diary where he kept his medical observations.

He was born around 250/864 in Rayy, Iran. He first studied mathematics and astronomy, and devoted himself to the arts, music and alchemy. It was only later that he became involved in medicine.

He is one of the encyclopaedic minds gifted in both speculation and experimentation, never able to limit himself to a single subject. With an eager and restless nature, he resembles the men of the Renaissance, Paracelsus for instance, who dedicate themselves with passion to their studies, risking their life, marking everything they do with their powerful personality, more tumultuous than balanced.

We are not going to deal here with his immense medical work, the *Ḥāwī* or the *Manṣūrī* which, translated into Latin in the Middle Ages, was for a long time a basic book for Western doctors. Let us consider just his alchemic work, one of the most important in the Middle Ages, and which is condensed in his *Sirr al-asrār* (in Latin, *Secretum secretorum*).

Although al-Rāzī did not accept Jābir's complex theory on 'the balance', he believed that at the base of all substances there were four 'elements' and that therefore the transmutation of metals was possible. The object of alchemy is double: it teaches on the one hand how to transform the non-precious metals into silver or gold, and on the other hand how to convert the quartz, or even simple glass, into precious stones, emeralds, sapphires, rubies, etc. And all this through appropriate elixirs. It is remarkable that al-Rāzī never calls his elixirs by 'the philosophical stone'. He accepts Jābir's theory on the composition of metals of sulphur and mercury to which he sometimes joins a third element of a saline nature.

But the interest of al-Rāzī lies particularly in his practical chemistry. His *Secretum secretorum* gives for the first time a clear division of chemical substances; and he prefers positive laboratory work to theoretical imaginings without basis. From his description of tools it seems that his laboratory was well furnished. He mentions the following.

(a) Tools which serve for melting substances (*li-tadhwīb*): hearth (*kūr*), bellows (*minfākh aw ziqq*), crucible (*bawtaqa*), the *botus barbatus* (*būt bar būt*) of the medieval chemists, ladle (*mighrafa aw milʿaqa*), tongs (*māsik aw kalbatān*), scissors (*miqṭaʿ*), hammer (*mukassir*), file (*mibrad*).

(b) Tools for the preparation of drugs (*li-tadbīr al-ʿaqāqīr*): the cucurbite and the still with an evacuation tube (*qarʿ aw anbīq dhū-khatm*), a receiving matras (*qābila*), a 'blind still' (i.e. without an evacuation tube) (*al-anbīq al-aʿmā*), the *aludel* (*al-uthāl*), goblets (*qadaḥ*), flasks (*qārūra*, plural *qawārīr*), rosewater flasks (*mā' wardiyya*), cauldron (*marjal aw tanjīr*), earthenware pots varnished on the inside with their lids (*qudūr wa makabbāt*), water-bath or sand-bath (*qadr*), oven (*al-tannūr* which became *Athanor* in Latin), small cylindrical oven used to heat aludel (*mustawqid*), funnels, sieves, filters etc.

As for the chemical operations indicated by al-Rāzī, they comprise distillation (*al-taqṭīr*), calcination (*al-tashwiya*), solution (*al-taḥlīl*), evaporation (*tabkhīr*), crystallization (*al-tabalwur*), sublimation (*al-tasʿīd*), filtration (*al-tarshīḥ*), amalgamation (*al-talghīm*), ceration (*al-tashmīʿ*), this last consisting of converting the substance into a thick paste or fusible solid.

The substances used in alchemy cover the three natural kingdoms. It is the first time that we find such a systematic classification. The list of these products as mentioned in *Sirr al-asrār* is as follows:

A The earthly substances (*al-ʿaqāqīr al-turābiyya*) Mineral substances

1 The SPIRITS (*al-arwāḥ*)
Mercury, sal ammoniac, arsenic sulphate (orpiment and realgar), sulphur
2 The BODIES (*al-ajsād*)
Gold, silver, copper, iron, lead, tin, *Kharsind*
3 The STONES (*al-aḥjār*)
Pyrites (*marqashita*), iron oxide (*daws*), zinc oxide (*tūtiyā*), azurite, malachite, turquoise, haematite, arsenic oxide, lead sulphate (*kohl*), mica and asbestos, gypsum, glass
4 The VITRIOLS (*al-zājāt*)
Black, alums (*al-shubūb*), white (*qalqadīs*), green (*qalqand*), yellow (*qulqutar*), red
5 BORAX (*al-bawāriq*)
6 The SALTS (*al-amlāḥ*)

B Vegetable substances
Rarely used, they are mainly employed by physicians
C Animal substances
Hair, scalp, brain, bile, blood, milk, urine, eggs, horn, shell

To these 'natural substances' we need to add a certain number of artificially obtained substances; al-Rāzī mentions litharge, lead oxide, verdigris, copper oxide, zinc oxide, cinnabar, caustic soda, a solution of polysulphur of calcium and other alloys.

The insistence of al-Rāzī in promoting research work in the laboratory brought its fruits in pharmacy. Thus Abū al-Manṣūr al-Muwaffaq, a Persian of the end of the tenth century, mentions for the first time some chemical facts to distinguish certain medicines.[43]

## The *Turba philosophorum*[44]

In one of his books Jābir ibn Ḥayyān reports that a certain number of ancient philosophers – among them Hermes, Pythagoras, Socrates, Aristotle and Democritus – met to discuss alchemic problems. It was one of the first appearances of the theme of the 'assembly of philosophers', treated in a characteristic fashion in the work *Turba philosophorum*, very much used by Western alchemists.

The Latin version undoubtedly contains signs of having been translated from Arabic, but the discourse contained there show that the material used was mainly Greek. In 1931 Ruska published a detailed monograph concerning this work and proved in a definitive way that its origin was an Arabic text from between the ninth and eleventh centuries. Ruska's opinion was fully confirmed when Stapleton managed to show that a treatise from Ibn Umayl, a tenth century alchemist, contained fragments of the *Turba*. Plessner discovered there an Indian reference transmitted to the Arabs by the translation of a *Book of Poisons* by the Indian author Kautilya. In his posthumous work in 1975, Plessner identified the Arabic original with the *Book of the Assembly*.

In the Latin text we see nine philosophers that Plessner managed to identify: Anaximander, Anaximenes, Anaxagoras, Empedocles, Archelaos, Leucippus, Ecphantus, Pythagoras and Xenophanes, all pre-Socratic philosophers. The author used their ideas. In Xenophanes's text the aim of the book is clear. It tries to establish three theses: (1) that the creator of the world is Allāh, the God of Islam; (2) that the world is of a uniform nature; (3) that all the creatures from the superior world and the inferior world are composed of four elements. The preliminary text finishes here and the sixty-three texts that follow are purely alchemic.

Two other interesting facts were discovered by Plessner. First, the nine pre-Socratic philosophers of the *Turba* appear in the book of one of the first Christian Greek authors, Hippolytus (*c.* 222 AD), entitled *Refutation of All the Heresies*, and we note a close connection between the *Turba* and this book. Second, we find in an alchemic book by Olympiodorus (*c.* sixth century AD) parallels established between the doctrines of the great alchemists and those of philosophers, with the same desire of relating cosmological theories and alchemic theories. It seems then that the author of the *Turba* tried to establish a synthesis between a pre-Socratic doxography, alchemic ideas and the Qur'an.

## Ibn Umayl[45]

Muḥammad ibn Umayl al-Tamīmī is a contemporary of al-Majrīṭī, i.e. from the eleventh century. His life is not very well known but one of his texts has survived: *Kitāb al-mā' al-waraqī wa-l-arḍ al-najmiyya* (*The Book on Silvered Water and Starry Earth*) which is a commentary of his own alchemic poem *Risālat al-shams wa-l-hilāl* (*The Epistle on the Sun and the Crescent*). The two works were translated into Latin in the Middle Ages, the first entitled *Tabula Chemica* and attributed to Senior Zadith, son of Hamuel, and the second entitled *Epistula solis et Lunam crescentem*.

The first one is valuable for the history of alchemy because of its numerous quotations from ancient authors: it marks the degree of penetration of the hermetic ideas in Arabic alchemy. Stapleton and Lewis have shown that some quotations are of Greek origin; others are probably apocryphal and come from Arab authors.

To give an idea of the difficulties presented by some texts from later Arab alchemists, we summarize the introduction written by Ibn Umayl for his treatise *Kitāb al-Mā' al-waraqī*. He describes allegorically different operations which lead to the obtaining of the philosophical stone. He tells how, twice, he returned to Būṣir al-Sidr, in Egypt, and from there headed for an ancient temple. The guards opened the door for him. He saw on the ceiling of the gallery the image of nine eagles, their wings spread as if they were flying, with long claws. Each eagle held in its claws a drawn bow and arrow.

To the right and left of the gallery there were men of great beauty, richly dressed in bright colours. They pointed to an old man seated in the gallery in front of the front door. He was seated on a chair and had between his hands, on his knees, a stone table like an open book. He seemed to be inviting everyone to look to what was inscribed there.

The table was divided into two parts. At the bottom of the left part there was an image of two birds whose breasts were joined together. One of them had its wings cut and the other, hanging over the first, had intact wings. Each held the tail of the other as if the one with wings was trying to pull the other, which was resisting. The two birds formed a kind of circle, the symbol of 'two in one'.

Above the flying bird there was a circle. And above the two birds, at the top of the table, there was the image of a crescent. At the side of this was a circle similar to the one below next to the two birds. The whole contained five symbols: three at the bottom (the birds and the circle) and at the top the crescent and the other circle.

On the right side of the stone table there was an image of the sun with two rays as if they were the symbol of 'two in one', and at the side of them there was another sun with a descending ray. There were three things then, i.e. three lights, the two rays of 'two in one', and the descending ray to the base of the stone table.

The rays surround a black circle from which a third is separated, which gives one third and two thirds. One of the thirds has the shape of a crescent, its interior white. The black circle surrounds it. These figures represent the 'two in one'. What is at the bottom is 'one of the two' and these last are the black circle and the crescent inside the circle.

There are also two suns at the top: the figure of 'two in one', and the sun, which is the figure of 'one in one'. Therefore there are five elements on the right side of the table as on the other side. The total is ten, which corresponds to the number of eagles and of black earth.

This complex allegory, which resembles a night vision in a dream, is supposed to symbolize the different operations (fixation, sublimation, coagulation, etc.) which lead to the obtaining of the philosophical stone. Some of the elements represent different chemical products which are used as a starting point (copper, silver, sulphur, magnesium, etc.). Following this introduction a poem of 448 hemistiches is supposed to explain the image described above. The poem is entitled *Risālat al-shams ilā-l-hilāl* (*Letter from the Sun to the Moon*) and a long commentary, in prose, explains the different parts. It is this last treatise which actually constitutes the *Māʾ al-waraqī*. It is of great interest from the point of view of the history of alchemy with the Arabs as it contains numerous quotations from ancient authors.

## Al-Majrīṭī[46]

In Andalusia, under the Caliphat of al-Ḥakam II (961–76) flourished scholars in all the domains, including alchemy. One of these was Maslama b. Aḥmad, from Cordoba, better known under the name al-Majrīṭī because he lived for a long time in Madrid. He assimilated Muslim sciences in the Arab Orient where he seems to have had close contacts with the originators of the famous *Epistles of Ikhwān al-Ṣafāʾ*. He brought to Spain a new edition of this encyclopaedia. He is known in particular for his astronomical work: a revision of the Persian astronomical tables in Arabic chronology, a commentary on the *Planispherium* of Ptolemy and a treatise on the astrolabe. The last two were translated quite early into Latin and were very successful.

An important alchemic work, *Rutbatʿ al-Ḥakīm wa mudkhal al-taʿlīm* (*Rank of the Wise Man and Isagoge of Teaching*), is attributed to him, and an astrological work called *Ghāyat al-Ḥakīm*. The last was translated into Spanish in 1256 by order of Alfonso the Wise, King of Castile and Leon (from 1252 to 1284), and later it became popular in Latin under the name of *Picatrix*. Rabelais in *Pantagruel* mentions it when he speaks of the 'Reverend Father of Devil Picatrix, rector of the diabolic faculty in Toledo'. The attribution of the book to al-Majrīṭī was considered false as the internal critique shows that this work could only have been written after 1009, while al-Majrīṭī died in 1007.

Holmyard redeveloped an interest in *Rutbat al-Ḥakīm*. The author first expresses his views on the way an aspiring alchemist should be educated: by study mathematics, books from Euclid and Ptolemy, natural sciences with Aristotle or Apollonius of Tyana; then he needs to acquire a manual ability and practise precise observation, reasoning about chemical substances and their reactions; in his research he needs to follow the laws of nature, like a physician: a physician diagnoses the disease and administers the medicine, but it is Nature who acts.

Second, *Rutbat al-Ḥakīm* contains precise and understandable instructions about the purification of gold and silver by coupellation or other means, which shows that the author knew laboratory practice. Third, the author describes the preparation of mercury oxide on a quantitative base.

### Johannes Garlandus (*The Book of Alums and Salts*)[47]

From this important text of the eleventh and twelfth centuries, probably coming from Spain, there are now only fragments in Arabic. Neither the name of the author nor the title are known. The book was translated twice into Latin. One edition was printed in Basel in 1560 under a false name and with the title 'Johannes Garlundus, *De mineralibus liber*'. The second version is incomplete in several manuscripts and has been edited by Steele. This second version was used by Vincent of Beauvais in his *Speculum naturale* and *Speculum doctrinale*. It has been attributed to Rhazes but Ruska showed that this attribution is false. The work contains four chapters: (1) About arsenic, sulphur and mercury; (2) The metals; (3) Glass and precious stones; (4) The alums and salts. It is already experimental chemistry stripped of all astrological and gnostic considerations. His main sources are Jābir and Rhazes.

### Al-Ṭughrā'ī[48]

This alchemist, who was a civil servant under the Seljuks Malik-shāh and Muḥammad, has great importance as a poet and a writer. His *Lāmiyyat al-ʿajam* is very famous. He was executed in 1121.

In his *Nihāya*, Jaldakī tries to appraise the scientific value of al-Ṭughrā'ī: he was the most important alchemist since Jābir; his style has become perfect but his books can only be read by those who are already advanced in the great art. In his *Kitāb al-Masābīḥ wa-l-mafātīḥ* (*The Lamps and the Keys*), he reports the teaching of the Ancients; he is more theoretical than practical. He declares in his poem that he has inherited his alchemic knowledge from Hermes. According to Jaldakī, his most important book on alchemy is *Mafātīḥ al-raḥma wa masābīḥ al-ḥikma*.

### Ibn Arfaʿ Ra's[49]

Ibn Arfaʿ Ra's was very famous among later alchemists because of his alchemic poem *Shudhūr al-dhahab* (*Gold particles*), of great literary perfection. It is composed of 1460 verses having as rhymes the twenty-eight letters of the Arabic alphabet. The author follows the allegorical-mystical tradition, quite obscure, of his predecessors: Ibn Umayl, Abū al-Iṣbaʿ,

al-Ṭughrā'ī and Pseudo-Khālid. The eloquence and elegance of this poem gave its author the nickname *Shāʿir al-ḥukamā' wa ḥakīm al-shuʿarā* (the poet of the wises and the wise of the poets). He tried to give a commentary of his poem in the form of a dialogue with his disciple Abū al-Qāsim Muḥammad b. ʿAbdallāh al-Anṣārī.

### Abū al-Qāsim al-ʿIrāqī[50]

Also called al-Sīmāwī, Abū al-Qāsim al-ʿIrāqī probably lived in the thirteenth century. His life-story is not very well known. His principal work is *Kitāb al-ʿilm al-muktasab fī zirāʿat al-dhahab* (*The Science Acquired on the Subject of the Culture of Gold*), published with an English translation and a commentary by Holmyard in 1923. The book gives a good idea of the alchemic doctrines of the time.

Although not very original, he merited an abundant commentary by an author of the first half of the fourteenth century (died in Cairo in 1341), Aydamar al-Jaldakī, in his book *Nihāyat al-ṭalab fī sharḥ al-muktasab*.

### Jaldakī (d. 743/1341)[51]

ʿIzz al-Dīn Aydamar b. ʿAlī al-Jaldakī came from Jaldak, a township of Khurāsān, about 15 kilometres from Mashhad. He is certainly the most important representative of later Arabic alchemic thought. Although he did not have a creative mind, he collected in several works – which are mainly commentaries and compilations – a considerable number of texts from his predecessors.

He faithfully reproduces the texts which he reports. He respects the Jabirian conception of alchemy but for all that he does not renounce the allegorism and the hermetism, as we can see in his great commentary of the *al-Mā' al-waraqī* from Ibn Umayl. His *Kitāb Nihāyat al-ṭalab fī sharḥ al-Muktasab* of Sīmāwī is an immense commentary full of texts from ancient authors. Numerous poems (*Shudhūr al-dhahab*) are mentioned as well as Ṭughrā'ī and ancient Greek authors: Pythagoras, Hermes, Ostanes, Democritus, Zosimus, etc.

Under the title *Kashf al-asrār* he commented the famous *Nūniyya* of Abū al-Iṣbaʿ b. Tamman al-ʿIrāqī. Among his other commentaries we can mention the *Kitāb Ghāyat al-surūr fī sharḥ al-ṣudūr* of Ibn Arfaʿ Ra's, the *Kitāb Lawāmiʿ al-afkar al-muḍī'a* which is a commentary of the *Risālat al-shams ilā-l-hilāl* of Ibn Umayl, etc.

Finally, he dedicated a special treatise to the philosophical stone, *Kitāb anwār al-durar fī īḍāḥ al-ḥajar*, where in ten chapters he exposes the theory of the elixir: its essence, its unity, its qualities, its sublimation, its distillation, its purification, etc.[52]

## THE REFUTATION OF ALCHEMY: AVICENNA AND IBN KHALDŪN

### Avicenna (d. 428/1037)[53]

Avicenna is mainly known as the author of *Shifā'* and of the *Canon of Medicine*, i.e. as a philosopher and a physician. It is under this title that he gained the admiration of his contemporaries in the Middle Ages, in both West and East. Was he also a 'chemist' or, to use the language of his time, 'alchemist', believing in the transmutation of metals, researching the 'philosophical stone' and trying to obtain it?

Ruska, in 1934, dedicates an important article to the analysis of this question.[54] With regard to Avicenna's own attitude to alchemy, the solution seems to be so clear that all doubt must be rejected: there are formal texts where he condemns it in a very firm way, in particular in his *risāla* on astrology and, in a more elaborate way, in his treatise on the minerals. From this point of view the agreement of specialists on Avicenna is unanimous. The only point in dispute concerns the authenticity of a treatise entitled precisely *Risālat al-iksīr* which has always been attributed to him in the Latin Middle Ages and which Ruska rejects as apocryphal. At the end of his critical edition, Ahmed Atech, from the University of Istanbul, strongly affirms its authenticity.[55] How then to reconcile the latter information with the preceding positions?

Let us first consider the problem from the Western point of view. If we consult the classical collections of alchemic works such as can be found in the *Theatrum chemicum* of Zetzner or the *Bibliotheca chemica* of Manget, we find the following works attributed to Avicenna:

1 *Liber Aboali Abincine de Anima in arte Alchemiae*
2 *Declaratio Lapis physici Avicennae filio sui Aboali*
3 *Avicennae de congelatione et conglutinatione lapidum*
4 *Avicennae ad Hasen Regem epistola de Re recta*

The *De anima* is the most important in volume and as an influence in the Western Middle Ages. Vincent of Beauvais quotes it in a large number of articles; the extracts that he gives relate mainly to metals, which proves that the treatise existed in its Latin form already in the middle of the twelfth century.

Berthelot and Steinschneider considered the manuscript as authentic with interpolations. Ruska, in contrast, showed that it was falsified in Spain at the beginning of the twelfth century. Among the arguments that he brings forward against its authenticity, Ruska notes the absence of dedication to a Mecene contemporary of Avicenna and of any allusion to the East (to localities or to special products from the East), whereas there is a series of details which betray the Spanish origin of the compilator. Certain words, still in their Arabic form, show that the latter used an Arabic work: *alambic*, *tutia*, *aludel*, *azoch*, everyday words used in the Western alchemic literature. Others are more rare, like *bellote* from the Arabic *ballūṭ* (oak acorn); *attozonji* or *artozonji* from the Arabic *atrong*, lemon; *orrez* (rice); *zoala* for *Zuḥal* (Saturn); *amostari* for al-Mushtarī (Jupiter). A word like *morabetini* to designate a coin from the times of the Almoravids (*al-Murābiṭūn*) is specifically Andalusian.

Berthelot[56] and Ruska[57] have given us a detailed analysis of this book. They reproduced in particular three lists of names mentioned by the author of *De anima*; the third mentions John the Evangelist, priest of Alexandria, Garcia the Cardinal, Gilbert the Cardinal.... However, no Arabic work of Avicenna exists which corresponds at all to this treatise. At the time of the celebrations of Avicenna's millennium, all the libraries containing Avicenna's manuscripts were carefully inventoried: no Arabic manuscript corresponding to the Latin treatise mentioned above was found. The *De anima* of the *Shifā'* (*Liber sextum naturalium*) has nothing to do with alchemy. It is therefore necessary to separate definitively from the authentic works of Avicenna the Latin alchemic treatise which was attributed to him in the Middle Ages.

As for the second treatise, *Declaratio Lapis physici Avicennae filio sui Aboali*, its apocryphal character is obvious from the title which confuses the *kunya* (surname) of Avicenne, Abū ʿAlī, with the name of his son. ... Ruska showed that the Latin author of this pamphlet used not an Arabic original (we cannot find technical terms betraying an Arabic origin) but texts in the tradition of the *Turba philosophorum* and the *De anima* of Pseudo-Avicenna. Certainly no Arabic text corresponds to a similar epistle.

With the third treatise *Avicennae de congelatione et conglutinatione lapidum* we are on more solid ground. The text in question belongs in effect to the *Shifā'* of Avicenna and was edited in a critical way in 1965.[58] It was believed for some time that it was part of Aristotle's writings and it was called *Liber de mineralibus Aristotelis*. It was published in translations with the *Meteorologica* of Aristotle as forming the last three chapters of the fourth book. Around 1200, Alfred of Sarashel translated, making some cuts, the part dedicated to the formation of minerals. It was put as an appendix to the fourth book of the *Meteorologica* translated from Greek by the Sicilian Henry Aristippus, while the first three books were translated from Arabic by Gerard of Cremona. This set formed what is called the *vetus versio* among the two Latin versions used in the Middle Ages.

*The Book of Minerals*, entitled in Arabic *Kitāb al-maʿādin wa-l-āthār*, contains two sections. The first studies what we call physical geography of the earth. The second studies the events and the inanimate bodies on the surface of the earth.

After discussing the mountains, the sources of water, etc., Avicenna comes to the 'mineral substances' and their properties, and then to alchemy and the alchemists' pretension of transmuting lead into gold. We can summarize his doctrine in the three following propositions.

1 The metals are composed of mercury and sulphur in different proportions and they are *specifically* different.
2 What contributes to give to each metal its specific difference is, in addition to the proportions of mercury and sulphur their degree of purity. In this way mercury can be pure (*naqī*), of good substance (*jayyid al-jawhar*), bad (*radī'*), impure (*danis*), without cohesion (*mutakhalkhil*), earthly (*arḍī*), good (*jayyid*), having heavy clay (*thaqīlatun ṭīnatuhu*). Also, sulphur can be white (*abyaḍ*), brighter (*anṣaʿ*), better (*afḍal*), pure (*naqī*), impure (*ghayr naqī*), possessing dyeing, firy, pervasive, incombustible power (*quwwa sabbāgha nāriyya laṭīfa ghayr muḥriqa*), combustible (*fīhi quwwa iḥtirāqiyya*), dirty (*darin*), polluted (*nājis*), not easily mixed (*ghayr shadīd al-mukhālaṭa*), fetid (*munattin*).
3 By ingenious procedures skilful artisans can 'dye' the metals in order to give them the outside resemblance of silver or gold but they cannot in any way obtain their transmutation. The fabrication of silver or gold from other metals is practically impossible and unsustainable from a scientific and philosophical point of view.

We find confirmation of Avicenna's position in a treatise attributed to him entitled *Risālat fī ithbāt aḥkām al-nujūm* or *al-Ishāra ilā ʿilm fasād aḥkām al-nujūm*.[59] After a short introduction where he expounds the reasons which led him to write this treatise, Avicenna gives some thoughts about the motives that have pushed men to be interested in alchemy:

> The preference of man for rest and an easy life made him believe that the acquisition of these goods is only possible through wealth and that this can only be acquired, except for rare cases of inheritance or an extraordinary windfall, by a lot of pain and work; consequently some have imagined a way of finding this wealth without effort and without pain and invented alchemy as a method and the most sure science to change all vile metal into silver and silver into gold. They have left numerous books on this subject, for instance Jābir's writings, and those of Ibn Zakariyyā al-Rāzī. These are absurdities

> because, for everything that God created through the force of nature, artificial imitation is impossible; on the contrary artificial and scientific productions do not belong in any way to nature.

Let us come now to the *Risalāt al-Iksīr* whose critical edition has been published by Ahmed Atech. Ruska, in his article on the chemistry of Avicenna, dedicated some pages to it, basing himself uniquely on the Latin text, and arrived at the conclusion that the treatise is not authentic; according to him it is the work of an Andalusian author and then passed from West to East.

The *Risālat al-Iksīr* comprises a short introduction and nine chapters. In the introduction, Avicenna says that there was an exchange with a contemporary scholar[60] on the subject 'of what is hidden in the Art' (of alchemy). The latter asked him for a report summarizing the results that Avicenna had reached at the end of 'his reflections, interpretations and meditations'.

In the first chapter Avicenna exposes the general principles which are at the base of chemistry as an operational technique. He reproves the alchemy partisans and his detractors for lack of rigour in their argumentation. Then he poses the problem in clear terms: it is about

> finding a dye that fire will not corrupt, a substance which will mix with metals, a substance which will weld, a substance which will coagulate and stabilize on the fire, and an ingenious method (*ḥīla*) to mix these products in order to obtain only one substance
>
> (a) that the fire cannot dissociate,
> (b) that dyes as a result of the dye contained in it,
> (c) that mixes as a result of the mixing substance contained in it,
> (d) that welds as a result of the weld substance contained in it,
> (e) that fixes forever as a result of the stabilizing substance contained in it.

The following chapters describe in detail the way to prepare these different substances: whitening dye using mercury purified by sublimation and made friable, 'reddening' dye obtained from sulphur purified from arsenic etc. Then he talks about the composition of these different substances, of the utilization of non-mineral matter, of calcination and solution procedures. The treatise culminates with a description of the elixir as follows:

> This elixir dyes by its dye, it immerses by its fatty matter. The grease is what binds the dye, which is very pervasive, with the lime, which is very thick, and with water. If the grease which binds (*al-muqawwim*) in the lime dyes in the dye, the two become immersed with it, and if the lime is fixed the two are bound because of the force of the mixture. Example of red dye amongst the elements – fire; example of grease – air; example of mercury – water; example of lime – earth. White is achieved through all four.

In his article about this treatise, Atech responds to Ruska's objections to its authenticity in a way that seems convincing to us. To the primary objection according to which Avicenna attacked gold manufacturers in the *Shifā'*, one could respond rigorously that he changed his opinion. But, says Atech, that is not necessary because Avicenna does not speak in his *Risālat al-Iksīr* of transmutation of metals but of 'dye', and does not state anything different in the *Shifā'*. And, as confirmation, the Turkish scholar adds that all the manuscripts without exception attribute it to Avicenna; two of these manuscripts are very ancient (588/1192 and 699/1290).

However, in his introduction Avicenna does show not a reserved attitude with regard to alchemy because he declares that 'those who have most merit and science contradict the followers of transmutation and reject their opinion as false'. He adds that having read their books he found their argumentation weak and their content on the whole rambles and digresses. These are not thoughts of an enthusiastic partisan of alchemy. Wishing to keep a strict objectivity he prefers to examine the problem and make experiments which definitely confirm his philosophical deductions.

It seems to us that the solution should be looked for in a chronological examination of Avicenna's works. Taking into consideration Avicenna's autobiography finished by his disciple Jawzajānī, we can divide his life into six periods. It is in the second period, his travels, that he meets Abū al-Ḥasan al-Sahlī to whom the *Risālat al-Iksīr* is dedicated, and the experiments that he describes must have been done before. Thus he went through a period of expectation, of research, wanting to investigate for himself the alchemists' allegations. Little by little his conviction gets stronger: the disdainful remarks at the beginning of this *Risāla* regarding alchemists and their weakness, from the philosophical point of view, give place to a pure and simple rejection of their pseudo-scientific pretensions. However, he keeps the certainty that in this domain, the ability of the alleged gold manufacturers can go very far, to the point of misleading the most wise. Our explanation seems to us to maintain at the same time the authenticity of the *Risālat al-Iksīr* and the basic philosophical position of Avicenna with regard to alchemy.

### Ibn Khaldūn (d. 809/1406)[61]

The famous author of the *Muqaddima* dedicates two chapters of his work to alchemy. In the first chapter (chapter 23) entitled *Fī 'ilm al-kīmyā'* he defines alchemy, quotes a certain number of its followers, and reproduces in full the *Risāla* of Ibn Bishrūn who expounds the essentials of the alchemic technique. In a second chapter (chapter 26), entitled *Fī inkār thamrat al-kīmyā' wa istiḥālat wujūdihā wa mā yanshā' min al-mafāsid 'an* *intiḥālihā*, he denies the alleged fruits of this science and shows that it is impossible and that its practice entails serious disadvantages from a social point of view.

### Definition of alchemy: its basic procedure

Ibn Khaldūn starts by defining the object of a 'science of alchemy': 'it studies matter through the intermediary of which one can achieve the generation of gold and silver by means of the Art (*bi-l-ṣināʿa*) and explains the workings that lead there process'.

Where can we find this matter and how should we prepare it, or arrange it? The alchemists addressed themselves to very different objects: not only minerals (*al-maʿādin*) but also bones, feathers, hair, eggs, excrement. By classical operations such as the resolution of bodies into their natural parts using sublimation and distillation, by solidification of liquids through calcination, the pulverization of bodies using pestle and mortar etc. By these operations, the alchemists intend to obtain a 'natural body' (*jism ṭabīʿi*), the elixir which, thrown over a hot mineral body (lead for instance or tin or copper), converts it into pure gold.

### The ancient alchemists: the alchemy under magic

Many authors, according to Ibn Khaldūn, have written since the most ancient times about alchemy but the great master is Jābir ibn Ḥayyān who composed seventy enigmatic treatises which we can only understand when we have knowledge of all the science they encompass. Other alchemists are mentioned: al-Ṭughrāʾī, Maslama al-Majrīṭī, who wrote about alchemy in *Rutbat al-Ḥakīm* as a companion to his work *Ghāyat al-Ḥakīm* dedicated to magic and talismans, Ibn al-Mughayribī, etc. Then Ibn Khaldūn reproduces an epistle about alchemy that Abū Bakr ibn Bishrūn, one of Maslama's students, had addressed to his colleague Ibn al-Samḥ, at the end of which he expresses his own ideas: 'you see (by the above) how (the author) has changed all expressions concerning the Art into the form of symbols and enigmas nearly impossible to understand. This proves that this is not a natural art (*ṣināʿa ṭabīʿiyya*) . . .'. What one must believe about alchemy, what is the truth confirmed by the facts, is that it comes in the category of influences from spiritual souls and their activity in the natural world, either as a wonderful thing (*karāma*), if the spirits are good, or as a kind of magic (*siḥr*) if the spirits are bad and dissolute.

In Chapter 26, Ibn Khaldūn undertakes a systematic refutation of alchemy. He starts by remarking that there are a lot of alchemists who, incapable of earning their living, have thought of becoming rich through alchemy. In fact they have only succeeded in ruining themselves and losing all credibility once the futility of their attempts is discovered. Others use pure and simple fraud, either openly or in secret: openly by for instance applying on top of silver jewellery a thin layer of gold or by covering copper objects with silver or even by alloying the two metals; in secret, by altering the look of certain metals through an artificial procedure, for instance whitening copper and covering it afterwards in sublimated mercury – it then looks like silver; only the most skilful experimenters are able to discover the fraud.

But not all alchemists are crooks: some are honest and in good faith believe in the possibility of the transmutation of metals; we can discuss with them although, as Ibn Khaldūn remarks twice, nobody in the world is known to have obtained the result looked for by means of alchemy. Everything reported about this subject are mere stories.

The famous historian undertakes then to refute the alchemists' pretension. After having reported the opinions of al-Fārābī, Avicenna and al-Ṭughrā'ī, he advances a certain number of arguments which he summarizes as follows.

> The essential of the alchemists' art and of what they expect to obtain by this treatment is to observe (*musāwaqa*) the metallic nature through artificial action and to imitate it (*muḥādhāt*) until generation of a metallic body is achieved or a matter is produced through forces, operations and a constitutional procedure which assimilates it to its form. For the action of the art is preceded by phases of the metallic nature which one wishes to imitate or follow, or on which one wishes the matter endowed with force to act with a detailed portrayal, phase after phase. But these steps are infinite; human science is powerless even to attain what is inferior to it. Alchemy resembles someone who wants to produce a man, an animal or a plant. Such are the essentials of this argument.

Ibn Khaldūn indicates other arguments, one of them taken from the social aspect of the venture: the divine wisdom wanted gold and silver, precious and rare metals, to be used to guarantee the profits and wealth of man; their disproportionate growth would make transactions useless and would run counter to divine wisdom. However, nature always uses the shortest way, very different from the long complex operations of the alchemist. Finally the comparisons used for the elixir are inadmissible because for instance the leaven only transforms the dough and prepares it for digestion; it is a corruption, an easy operation, whereas the transformation of metal to a more noble one and elevated one is a generation (*takwīn*) and an improvement (*ṣalāḥ*). At the end of these arguments, Ibn Khaldūn restates his position: 'alchemy can only be achieved through psychic influences (*bi-ta'thīrāt al-nufūs*). Extraordinary things are either miracles or witchcraft. . . . They are unbounded; nobody can claim to acquire them'.

This plea against alchemy by a mind as distinguished as Ibn Khaldūn must give partisans of alchemy envisaged as 'the fabrication of gold and silver' food for thought. As for the mystic aspect of alchemy as a means of purification of the soul, there is not a whisper either from Avicenna or from Ibn Khaldūn. We have to wait for the Western alchemists to engage in this path, and for the philosophical-gnostic speculations of Corbin to reveal them among our Arab authors.

At the end of our study, let us note that this negative attitude of Avicenna and Ibn Khaldūn is not the only one among Arab authors. A whole literature exists concerning the defence of the Great Art. Ullmann,[62] after Lippmann,[63] dedicated to this problem a whole section of his study on alchemy among the Arabs. Although al-Kindī[64] refutes alchemy's pretensions, in contrast al-Fārābī – who is still a 'philosopher' – affirms the legitimacy of this 'science',[65] as does Fakhr al-Dīn al-Rāzī.[66] The discussion remains open and, finally, it seems that in principle the problem is insolvable. Still today we find, in Egypt and elsewhere, passionate searchers for the philosophical stone who are never defeated by any failure.

What is certain is that the history of alchemy amongst the Arabs deserves consideration, seen from two points of view. On the one hand the experimental researches in the 'laboratories' of Arab alchemists led to the discovery of new chemical products and of some technological procedures useful in everyday life; on the other hand the speculations of some alchemists, where the data from ancient authors mingled with religious statements from the sacred texts, produced through the centuries an intense intellectual fermentation. From these points of view alchemy amongst the Arabs constitutes a link in the transmission of certain scientific and philosophical ideas from Antiquity to the modern world. In this regard it deserves the interest of historians of science.

## NOTES

For a global bibliography about alchemy see R. Halleux (1979).

1 Author of works on the synthesis of organic substances and on thermochemistry, he died in 1907. His works on the history of chemistry are important: M. Berthelot (1893, 1889, 1885).

2 Cf. 'Kīmyā', in *Encyclopédie de l'Islam* (1st edn) (Wiedemann) and *Encyclopédie de l'Islam* (2nd edn) (Ullmann); Lippmann (1919/27: I, pp. 60–3; II, pp. 50 *et seq.*); Doresse (1951: 116); Festugière (1944: 218).

3 For Pythagoras see *Encyclopédie de l'Islam* (2nd edn) Fīthāgūrus, and the posthumous work of M. Plessner (1975).
4 Ullmann (1972: 153).
5 Lippmann (1919/27: I, p. 108).
6 Ullmann (1972: 153–4); Sezgin (1971: 94–6); Kraus (1943: II, pp. 52–4).
7 Kraus (1943: II, p. 51) and Singer (1946: 115–28).
8 Cf. Pseudo-Plato and Badawi (1968: 42–3).
9 Ullmann (1972: 157).
10 Stapleton (1936: 129); Sezgin (1971: 102). See the work of Balīnūs quoted in note 24 later.
11 Kraus (1943: I, p. 66, no. 206).
12 Kraus (1943: II, pp. 122–34); Ullmann (1972: 158).
13 Kraus (1943: II, p. 326). Note that there is often ambiguity between Galen and Apollonius; see the presentation of the edition by Weisser, quoted in note 24 later.
14 Kraus (1943: I, p. 178).
15 Festugière (1944: pp. 25–6); Lippmann (1919/27: 44 *et seq.*); Ullmann (1972: 150).
16 Festugière (1944: 237).
17 *Ibid.*
18 *Ibid.*, pp. 237–8.
19 Festugière (1944: 263–82).
20 Holmyard (1957: 26).
21 There is at the moment an important controversy about this means of transmissions.
22 Ullmann (1972: 165–7; 289–91).
23 Fück (1951: 91, 114); Ruska (1926: 65–7).
24 Sezgin (1970–1: 163–5), Ullmann (1972: 171 *et seq.*). This text has been edited: Balīnūs al-Ḥakīm, *Sirr al-khalīqa wa ṣanaʿat al-ṭabīʿa*, edited by Ursula Weisser, Aleppo, IHAS, 1979. See also Corbin (1986).
25 Ruska (1926).
26 Berthelot (1888: 29/1); Lippmann (1919/27: I, pp. 60–3; II, pp. 5 *et seq.*); *Encyclopédie de l'Islam* (1st edn) under Aghāthūdhimūn (Plessner); *Real Enz.*, III (1918), pp. 32–60; Ullmann (1972: 175–6).
27 Ullmann (1972: 175).
28 Kraus (1943: II, p. 298). See note 24 above.
29 Berthelot (1893), III, pp. 34–78; Fr. tr. pp. 76–115; Ullmann (1972: 178–9). About the theory explained in this treatise see Sezgin (1971: 91–4).
30 Ullmann (1972: 180).
31 Kraus (1943: II, p. 43); Lippmann (1919/27: I, pp. 46–50; II, p. 142); Ullmann (1972: 181).
32 See Kraus (1943: 43); Ullmann (1972: 184); Bidez-Cumont (1938).
33 Ullmann (1972: 187–8).
34 Festugière (1944: 219).
35 Doresse (1951: 119).
36 Ruska (1924); Sezgin (1970–1: 121–2); Ullmann (1978).
37 Sezgin (1971: 128–31); Ullmann (1972: 195–6).

38 Ullmann (1972: 131).
39 Ullmann (1972: 196–7).
40 The basic work is from Kraus (1943); Sezgin (1970–1: 132–368); Jābir b. Ḥayyān, *Tadbīr al-iksīr al-aʿẓam* (fourteen treatises by Jābir on the great alchemic work), texts edited and presented by Pierre Lory, Damascus, IFEAD, 1988; Jābir b. Ḥayyān, *Dix traités d'alchimie. Les dix premiers traités du Livre des soixante-dix*, presented, translated from Arabic and commentated by Pierre Lory, Paris: Sindbad, 1983.
41 Holmyard (1957: 77).
42 Not to be confused with great theologian of the same name Fakhr al-Dīn al-Rāzī (d. 606/1209). For Rāzī the chemist, cf. *Encyclopédie de l'Islam* (1st edn), vol. III, pp. 1213–15 – a remarkable article from Kraus and Pinès with an abundant bibliography; *Fihrist*, pp. 299–302, 358; *GAL*, vol. I, p. 253 *et seq.*; al-Qifṭī, pp. 271–7; Leclerc (1876: vol. I, pp. 337–54); Pines (1936: 34–93) (Arabic translation by Abū Rīda, Cairo, 1946, pp. 45–90). Sezgin (1971: 275–82); Ullmann (1972: 210–12); Ruska (1922: 719–24).
43 Holmyard (1957: 88).
44 Ruska (1931: 1–368); Sezgin (1971: 213–16); Ullmann (1972: 60–5); see also the work of Plessner (1975).
45 Sezgin (1971: 288); Ullmann (1972: 217–18); Stapleton and Azo (1905: 47–70).
46 Holmyard (1957: 98); Sezgin (1971: 294–8); Ullmann (1972: 225–6); Pingree (1986).
47 Ullmann (1972: 228); Ruska (1935a).
48 Ullmann (1972: 229).
49 *Ibid.*, pp. 231–2.
50 *Ibid.*, p. 236.
51 We adopted this form following the correction by Henry Corbin (1986: 67) which is based on the fact that the village of origin of the author is called 'Jaldak'; Ullmann (1972: 237–42).
52 Cf. Berlin Catalogue 4187 (Lbg 1007, folios 54a–64a).
53 On Avicenna see the articles in the supplement of the *Dictionary of Scientific Biography*, vol. XV, pp. 494–501 (G. C. Anawati and Z. Iskandar); see also Anawati (1971; 1974: 6–17).
54 Ruska (1933: 14–51); Ruska was himself a professional chemist and started to dedicate himself to the history of this science among the Arabs when he was 50 years old. A few years later he became director of the Institute for the History of Natural Sciences in Berlin. See the review dedicated to him by Kraus (1938: 5–40).
55 Atech (1952a: 27–54; 1952b). Saidan ayribasin, pp. 47–62 with eight boards of manuscript. Synthesis of his position, in Arabic, in *al-Kitāb al-dhahabī li-l-mahrajān al-alfī li-dhikr Ibn Sīnā* (Baghdad, 20–28 March 1952), Cairo, 1952, pp. 60–4.
56 Berthelot (1893: 294–301).
57 Ruska (1933: 34–5).
58 *Al-maʿādin wa-l-āthār al-ʿulwiyya*, edition of the *Shifāʾ*, Cairo, 1965. This text had already been published by Holmyard and Mandeville, *Avicennae de congelatione lapidum, being sections of the Kitāb al-Shifāʾ*, Latin and Arabic texts

edited with an English translation and with critical notes, Paris, 1927. Note that the Arabic version of *Meteorologica* of Aristotle was edited by M. Casimir Petraitis: *The Arabic version of Aristotle's Meteorology*, a critical edition with an introduction and Greek–Arabic glossaries, Beyrouth: University of St Joseph (Research Series, vol. 39), 1966. See also Baffioni (1980: fasc. 2).

59 Mehren (1884: 383–403).

60 The Sheikh al-Sayyid Abū al-Ḥasan Sahl b. Muḥ. al-Suhalī.

61 See our article with this title (1974).

62 Ullmann (1972: 249–57).

63 Lippmann (1919/27: II, pp. 12–14). Cf. also Wiedemann (1908: 71–87) in *Journal für praktische Chemie* 184 (76).

64 *Ibṭāl daʿwa al-muddaʿīna ṣanʿat al-dhahab wa-l-fiḍḍa min ghayr maʿādinihā* (Refutation of those that want to manufacture gold and silver from other substances).

65 *Maqāla fī wujūb ṣināʿat al-kīmyā* (Treatise on the necessity of alchemic science).

66 *Mabāḥith*, II, pp. 214–18.

# 26

# *The reception of Arabic alchemy in the West*

ROBERT HALLEUX

Although everyone admits today that Latin alchemy from the Middle Ages is all founded on Arabic heritage, the transmission mechanisms have not yet been studied. The translations are not all discovered yet;[1] their Arabic model is not always identified, their manuscript tradition is not known; the translator is only mentioned in a small number of cases.

The Latin Early Middle Ages did not know alchemy, although the recipe literature (*Rezeptliteratur*) carried a number of formulae translated and collected from Greek alchemists but cut off from the conceptual context which would give it any sense.[2] Thus, the original nucleus of the *Mappae Clavicula*, treating the work on gold, precious stones and gems, is the translation of a Greek work 'the small key of handiwork' from which there are numerous fragments in the corpus of Greek alchemists.[3] But this alchemy is not recognized as such. Consequently the eruption of Arabic alchemy represents a complete novelty, at the same time full of promises and difficult to assimilate.

## FIRST INFILTRATIONS

It is often considered that the first mention of alchemy in the West is a passage from the chronicles of Adam of Bremen, reporting a fraudulent transmutation before the Bishop of Hamburg around 1050 by a Byzantine Jew named Paul.[4] In the absence of any other information we can suppose that Paul got his knowledge from Byzance, where the sacred art underwent a vigorous renewal at the time of Psellos.[5]

It is paradoxically in Saxony, away from the penetration centres of Arabic science, that we find the first certain traces. It is a famous passage from *A Brief Description of Different Arts* (*Diversarum artium schedula*) from the monk Theophilus, pseudonym of the Benedictine Roger of Helmarshausen (between 1106 and 1140, probably *c.* 1125).[6]

> There is also a gold, called Spanish gold, which is prepared from red copper, powder of basilisk and human blood and vinegar. The heathen, who are said to be skilled in this art, produce basilisks for themselves in this way.
>
> They have a structure under the ground, made above, below and all round with stones, with two tiny openings, so small that scarcely any light can be seen through them. In this place two old fowls, twelve or fifteen years old, and they give them plenty to eat. When they have become plump, with the heat of their fatness they copulate and lay eggs. When these have been laid, the fowls are taken away and toads are introduced to sit on the eggs, and bread is given them for food. When the eggs are hatched, male chicks emerge like hens' chicks. After seven days they grow the tails of serpents. If the structure were not paved with stone they would immediately enter the ground. Careful of this, their owners have round bronze vessels of large size, perforated everywhere and with narrow mouths, and they place the chicks in these, block up the mouths with copper lids, and bury them in the ground. For six months they are nourished with the fine earth entering through the holes. After this, they uncover the vessels and place them on a large fire until the beasts within are completely burned. When this has been done the vessels have cooled, they take them out and carefully grind them, adding a third part of the blood of a red-headed man, which has been dried and ground.
>
> These two compounds are mixed with sharp vinegar in a clean vessel. Then they take very thin sheets of pure red copper, and they smear this preparation over them on each side and put them on the fire. When they are white-hot, they take them off and quench theim in the same preparation and wash them, and so they proceed for a long time until this preparation eats through the copper, which, thereupon, takes on the weight and colour of gold. This gold is suitable for all work.[7]

Such a formula is surprising in the *Schedula* which is, as is known, a manual for the handiwork in a monastic environment and is a positive description of the daily work of the painter, the glass maker, the goldsmith. But the description of Spanish gold is placed in a context where Theophilus is forced to write it from second hand.

It could be the propaganda speech of a metal merchant, advertising his merchandise. But more probably, Theophilus uses a written source. The recipe itself is simple: to cement the red copper with basilisk ashes, probably the name of an alchemic code,[8] and with the blood of a red-haired man, the code name for mercury, liquid extracted from red cinnabar.[9] As for the generation of the basilisk, it belongs to the tradition of the beastiaries, although details furnished by Theophilus are not all proved.[10]

I recently identified the basilisk recipe with a chapter of long unedited *practica* preserved in the famous manuscript Palermo 40 Qq A 10 (early fourteenth century). This treatise, using animal substances, especially eggs and worms, for transmutation, seems to have been translated from an Arabic original, probably belonging to the Jabirian corpus. According to the twelfth century physician Magister Salernus, the recipe was known by Alphanus the Archbishop of Salerno (1058–85). The missing link between Salerno and Roger is Wibald (1098–1158), the abbot of Monte Cassino and Stavelot (the Belgian abbey where Roger was educated). Wibald himself was well acquainted with Salernitan and Spanish science, since he copied in his own Sacramentary (ms Brussels 2034–2035) one of the earliest extant Latin versions of the pseudo-Aristotelian *Secretum Secretorum*.[11]

To this same oldest stratum seem to belong the additions of Adelard of Bath to the *Mappae Clavicula*.[12] From a primitive nucleus taken from the Greek alchemists, the collection swelled during the Early Middle Ages with additions relating to painting, architecture, inflammable compositions etc.[13] In its final form, preserved in the famous manuscript from Corning Museum of Glass (twelfth century), two recipes (190, 191) contain words in Old English, and the recipes from 195 to 203 contain words in Arabic.[14] However, the manuscript London BL Royal 15 CIV (thirteenth century), folio 2v, giving a table of contents mentions as the last article *Liber magistri Adelardi Bathoniensis qui dicitur Mappae Clavicula*.[15] The corresponding text is not in the manuscript any more. Comparing the two indexes, Marcellin Berthelot concludes that the recipes in question had been added by Adelard to the *Mappae Clavicula*.[16]

The recipes contain three formulae for niello, one for gold coloration, one for refining of gold, one for gold-plating an alloy, one for silver coloration, three for soldering. The origin of the recipes is not easy to determine, although it presents some general resemblance to the recipes of *Liber sacerdotum*.[17]

That the *Mappae Clavicula* was reshaped by the translators in Spain is clear from a supplementary index found in the *Catalogue of Palermo* (MS 4° Qq 10, folio 371, beginning of the fourteenth century). It is the catalogue of the alchemical books which belonged, at the end of the thirteenth century, to Brother Dominique, monk in the convent of St Procolo in Bologne.[18] It reads (folio 371r, lines 25–6) after several titles of works in verse: *Item alium librum metricum qui dicitur mappa clavicule per Robertum translate de arabico in latinum qui incipit. Quere dei regnum* *prius et tibi cuncta dabuntur* (TK 1191). 'Also another book in verse entitled *Mappa clavicule*, translated by Robert from Arabic into Latin. It starts: "Look for the kingdom of God first and everything will be given to you".' Steinschneider saw in 'Robertus' the translator Robert of Ketton (from Chester or Retines), archdeacon of Pampelune.[19]

The manuscript from Brother Dominique is lost but Schipperges found the text in the manuscript Trier Stadtbibl, 1024/1936, fifteenth century, folio 163r a.[20] It comes with a short treatise about the colours and their mixtures entitled *Incipit mappae clavicula*. However, this text is found at the top of the manuscript Phillips Corning from the *Mappae Clavicula* before the original preface. It is preceded by a short poem of seven hexameters.

> Sensim per partes discuntur quaelibet artes/ Artis pictorum prior est factura colorum/ Post, ad mixturas convertat mens tua curas/ Tunc opus exerce, sed ad ungulum cuncta coerce/ Ut sit ad ornatum quod pinxeris, et quasi natum/ Postea multorum documentis ingeniorum/ Ars opus augebit, sicut liber iste docebit.

> Little by little, part by part, that all the arts are perfected. The art of the painters is preceded by the fabrication of the colours. Next, your spirit turns its senses to the mixtures. Then, start working, but submit everything to rigorousness, so that what you paint will be decorated and as natural. Next, through the proofs supplied by many ingenious minds, the art will improve the work as this book will show.

These hexameters were wrongly considered as the preface of Theophilus. In reality, this poem is interpolated in two manuscripts of Theophilus, the BL Egerton 840 A (*olim* Cambridge Trinity Ms R 15 5) from where Raspe has taken it for his edition, and the BN 6741 (manuscript of Jean le Bègue). These two manuscripts are interpolated with other extracts from the *Mappae Clavicula*.[21]

## THE TRANSLATIONS

With Robert of Chester, we engage on the more certain terrain of true translations. It is generally accepted that he dated his Latin translation of the *Morienus*[22] on the 11 February 1182 (in other words 1144). We know that this work, whose Arabic original is lost, describes the initiation of Khālid ibn Yazīd into alchemy by the monk Morienus (Marianos), disciple of Stephanus of Alexandria.[23] In other words the authenticity of the text was passionately contested although it does not disagree with what we know about Stephanus and his time.[24] Ruska even doubted the date of the translation itself.[25] In reality there is no reason to contest the testimony of the titles and texts of good manuscripts.[26] What passes for the preface of the translator includes the inscription of the three Hermes, Enoch, Noe, Hermes Trismegistus, announces the work as a novelty and apologizes about the difficulties found in its translation. This is not an argument against its attribution to Robert. In fact, although he had translated the Koran for Peter the Venerable the year before, the alchemical texts could have posed him new problems. Also, this preface is a moving text of which Lee Stavenhagen has shown that a short version existed, probably very old.[27] From *Morienus*, this preface has migrated into other texts, notably an astrological apocryphal text from the twelfth century entitled *Liber mercurii triplicis de VI rerum principiis.*[28]

We see in the preface the characterization of alchemy as *novitas*:

> qui nominatus est liber de Compositione Alchymiae. Et quoniam quid sit alchymia, et quae sit sua compositio, nondaum vestra cognovit latinitas, in praesenti sermons elucidabo. Posui *istud verbum*, licet ignotum et admirabile ut sub diffinitione claresceret. Hermes vero philosophus et alii qui post ipsum fuere hoc vocabulum ita diffiniunt, ut in libro de Substantiarum mutatione: Alchymia est substantia corporea ex uno, et per unum composita, preciosiora ad invicem per cognationem et effectum conjungens, et eadem naturali commixtione, ingeniis melioribus naturaliter convertens. In sequentibus vero hoc quod diximus explanabitur : ubi et de eius compositione ad plenum tractabitur.[29]

> This book styles itself the composition of alchemy. And as your Latin world does not yet know what alchemy is and what its composition is, I will clarify it in the present text. I gave this word, although unknown and surprising, so that it clarifies itself by definition. The philosopher Hermes and his successors defined this word as follows, for instance in the book of the mutation of substances: alchemy is a material substance taken from one and composed by one, joining between them the most precious substances by affinity and effect, and by the same natural mixture, naturally transforming them into better substances. Consequently what we have said will be explained and its composition will be regarded in detail.

The word 'alchemia' often designates the Stone, i.e. the transmutant agent. The preface reveals the knowledge of other texts. It seems there were previous translations. For instance the reflection on one (*ex uno et per unum*) makes us think of the *Emerald Table.*

We know that the *Emerald Table*, a small oracular text piously commented by generations of alchemists until the eighteenth century, belonged originally to the *Book of the Creature's Secrets* from Balīnās (Apollonius of Tyana), a cosmological encyclopedia which could go back to the seventh century.[30] The complete treatise was translated by Hugh of Santalla, who worked in Tarazona during these years, from 1145 to 1151.[31] Another version used by Albert the Great and Arnald of Villanova was edited by Dorothea Waley Singer and Robert Steele.[32] The *Table* is part of a doxographic treatise attributed to Hermes, clearly closer to the Arabic and full of Arabic names simply transcribed literally. This translation seems to have been carried out away from the others and the author is equally conscious of being a pioneer.

> Quaniam de opere philosophorum doctissimi desudaverunt, potius tractare disposuimus atque ab omni latinitate intractata quam maris alti natantes, singulariter pelagus investigare censuimus.

> Since the wisest men have sweated on the work of the philosophers, we have decided to treat a domain which the Latin world as a whole has not yet dealt with, like swimmers in the high seas, we have decided to explore alone the open sea.

With some doubt the editors attribute the translation to Plato of Tivoli. But the translation is followed by a paraphrase of the *Table* entitled *Expositio verborum Hermetis magistri philosophorum secundum veritatem nostram*, clearly written by a Christian.[33] One of these good manuscripts, the Oxford Bodleian Digby 119, folio 197, from the fourteenth century, originally from the south of France, adds the explicit *hic est editio verborum Hermetis juxta rationem Massiliensium*, which does not make any sense. But if *rationem* is a misreading of the abbreviation r, the correction 'R(aymundum) Massiliensem' would allow the identification of Raymond of Marseilles. We need to add that a part of this treatise is sometimes entitled *Liber de roberto*.[34]

According to the *vita* written by his disciples, Gerard of Cremona translated three alchemical works.[35] The first is entitled *Liber divinitatis de LXX* which corresponds to the title of the first of the *Seventy books* by Jābir ibn Ḥayyān. It is in reality a unique work. Each of the books, very brief, constitutes a chapter with a particular title. In the controversies about the author and his works the *LXX* is without question the one which has the most chance of representing the authentic thought of Jābir (eighth century).[36] Of all the alchemic translations, it is probably the most obscure. Jābir applies there the principle of dispersion of science. He never explains his ideas in detail, but he juxtaposes without any link the numerous themes which he refers to several times. Berthelot's edition, founded on the BN lat 7156 folio 66 va sq, gives us an incomplete text.[37] Even if we complete the manuscript with better ones, notably the Palermo 4° Qq A 10 folios 161–92, the text remains very obscure. The translator tried his best to transmit the words of his master but without explaining his reasoning. Also, in spite of the true fascination that Jābir has with the Latin alchemists, only some of his manipulations and his ideas, always the same ones, have followers. There are innumerable manuscripts which contain only a certain number of books, arranged in different orders. Furthermore the influence of Jābir was through other works like *The alums and the salts* and *De perfecto magisterio*. Finally alongside his *Septuaginta*, we need to make space for *Liber misericordiae* (*Kitāb al-raḥma*) translated at an unknown date[38] and for other small texts.[39]

In contrast, all is positive with the second translation from Gerard, the *De aluminibus et salibus*, whose Arabic original is preserved.[40] Written in Spain with Jabirian materials but in the spirit of Rāzī, it is a detailed classification of the alums (sulphates) and the salts with a description of the related operations. Through these two versions G and P and derived versions (like the *Liber claritatis*)[41] it has a decisive influence over all the operations side of Latin alchemy and more generally over mineralogy.[42]

As for the last alchemical work, the *Liber luminis luminum*[43] it is difficult to identify as the title is very common.[44] According to Richard Lemay, it is the treatise included in *Cum de sublimiori* (TK 290), again attributed to Rāzī or Aristotle.[45] It is a hidden 'theorica' using the *Septuaginta*. A manuscript from Kues says that it is a translation from Raymond of Marseilles.[46] Finally, a great classic of alchemy, the *De perfecto magisterio*, pseudo-Aristotelian, which is not a translation, refers to *Lumen luminum* as a work of the same author.[47] In the Paris manuscript BN lat 6514, the *De perfecto magisterio* is itself entitled *Lumen luminis* and *Perfecti magisterii* (folio 120 a) and is named in the explicit *Liber minoris translationis*. A critical edition of this text will be decisive. The *De perfecto magisterio*, a great treatise based on the *Meteorologica* of Aristotle, is divided into four parts giving the theory of the elements, the metals and their production, the technique of preparation, separations and the composition of elixirs.[48]

We have not so far disentangled the strands of the translations attributed to Gerard of Cremona. The encyclopaedist Arnold of Saxony (first half of the thirteenth century)[49] and following him Albert the Great[50] mention a lapidary from Aristotle's *Secundum translationem Gerardi*. This lapidary, whose Arabic text is preserved, is an spurious text from the medical schools of Syria and Persia in the seventh century, considerably enriched with alchemical elements belonging to the Latin tradition from Rāzī.[51] The translation, anonymous, is preserved in the manuscripts of Liege 77 and Montpellier 277. However, the passages mentioned by the two encyclopaedists, notably an important description of the compass, cannot be found there, and in addition the *Vita* does not mention any translation of this kind.[52]

With these few apparently well-known cases, numerous anonymous translations come from the same cultural area. Alchemy was an important part of the doctrinal corpus invading the West in this era. Thus the manuscript in Berlin, Staatsbibliothek R 956 (MS lat folio 307) copied in France in the second half of the twelfth century, which contains translations of astronomical and mathematical works,[53] also presents on folio 21b an *alchamia*, an interesting practice founded on the decomposition of organic substances (eggs).[54] The Arabic source is not identifiable, although some procedures make us think of Rāzī and one commentary mentions the Arab alchemist Artephius.[55]

In these conditions, a complete inventory of the translations is for the moment beyond the reach of research. Some manuscripts like Riccardianus 933 offer texts where the high density of Arabic words simply transliterated imply translations not yet identified. Moreover, the abundance of non-translated Arabic terms is an efficient criterion for the dating of these works.

Be that as it may, we can think that the majority of works were assimilated by the first decades of the thirteenth century. Texts from Albert the Great or Roger Bacon founded on extensive alchemical learning testify to the existence of an abundant translated literature.[56]

Some of these texts, such as the technical manual of Hermes, very often used by Arnold of Saxony[57] and close to the *Liber sacerdotum*, and the text of Ibn Juljul on the production of metals, discussed by Albert the Great,[58] seem to be lost today.

We do not know whether alchemy occupies a comparable place with the Angevin translators of the thirteenth century. The identification of the alchemist Efferarius Monachus with the translator Faraj ben Salim is hypothetical.[59]

Among the mass of the Arabic alchemy we cannot say the translators had made a choice: they translated practical texts (the *Liber secretorum* of Rāzī,[60] the *De aluminibus*) as well as theoretical texts (the *Liber trium verborum* of Khalīd),[61] treatises in the Aristotelian spirit (Artephius), the Platonian spirit (the *Liber platonis quartorum*)[62] or the Avicennian spirit (the *De anima in arte alchemiae*,[63] the *Epistola and Hasen regem*),[64] doxographies (the *Turba philosophorum*)[65] or highly esoteric works (the *Emerald Table*, Senior Zadith, alias Muḥammad Ibn Umayl al-Tamīmī).[66]

They have not always understood what they translated, contributing in this way to the obscurity of the subject. Thus, pure nonsense of the translator is expounded and allegorized for several centuries. However, it does not seem that the Arab teachers of the thirteenth and fourteenth century like al-ʿIrāqī[67] or Aydamar al-Jaldakī (around 1342)[68] were the object of translations.

## THE INTEGRATION

From the beginning of the thirteenth century, Latin culture was well informed about the new knowledge and became able to elaborate original works. Tradition attributes to Michael Scot (born before 1200, died around 1235)[69] an *Ars alchimiae* of which there are three very different versions.[70] The *nucleus*, probably authentic, reflects a practice already widely used, both in Islam and in Christianity,[71] and well approved in the apothecaries' business.[72] From the theories, Michael Scot retains just what he needs to introduce a collection of recipes largely dependent on the *De aluminibus et Salibus*. His *Liber Dedali philosophi*, also called *Lumen luminum* (incipit *cum rimarer*), uses the same materials to the point that it could pass for another version of the first work.[73] Michael Scot shows a concern, which is constant in the Latin world, to reduce the contradictions and obscurities of the old texts.[74] We touch here on the major problem that Arabic alchemy posed for the West.

Chiara Crisciani has shown that alchemy represented for the medieval West a *novitas* full of promises and threats.[75] Its practices seemed able to play a role in technological development. Its theories considerably enhanced the knowledge of the mineral world. In effect, on minerals and metals only the descriptions of Pliny and Isidorus, the pharmaceutical information from herbalists and the magical practices of the lapidaries were available.[76] However, the affirmation of a divine character, secret and revealed, and the language strategies which follow from there, constituted a clear obstacle to integration of the new knowledge.

The problem was posed among the translators. In 1143 Hermann of Carinthia, friend of Robert of Ketton, introduces alchemical elements into the cosmology of his *De essentiis*:[77] the idea that metals are generated by a seed,[78] and that mineral colours and the physico-chemical properties of metals come from the planets which preside over their generation.[79] These ideas are too general to be given a precise source. However, Hermann knew the book of Apollonius in the translation by his friend Hugh of Santalla: he mentions the description of the discovery of the *Emerald Table*[80] and one phrase of this oracular text.[81]

In Toledo, *De divisione philosophiae* from Gundisalvo refers to alchemy as one of the eight sciences subordinated to *scientia naturalis*, one of the three branches of theoretical science.[82]

> tunc scientia naturalis universalis est, quià octo scientiae sub ea continentur: scilicet scientia de medicina, scientia de iudiciis, scientia de nigromantia secundum physicam, scientia de navigatione, scientia de speculis, scientia de alquimia, que est scientia de conversione rerum in alias species; et haec octo sunt partes naturalis sciencie.

> Then the natural science is general, as eight sciences are included in it, i.e. the science of medicine, the science of judgements (judicial astrology), the science of necromancy according to nature, the science of navigation, the science of mirrors, the science of alchemy, which is the science of the conversion of things into other species; and here are the eight parts of natural science.

Further on, when he analyses the logical order of the Aristotelian corpus according to al-Fārābī,[83] the mineral world is not part of alchemy.

> Sexta vero pars est consideracio de eo, in quo communicant corpora composita similium parcium, que non sunt partes compositi diversarum parcium: et hec sunt corpora mineralia et species rerum mineralium; et de eo, quod est proprium unicuique speciei eorum et hoc docetur in libro qui intitulatur *de mineris*.

> The sixth part is the consideration of what is common to bodies composed of similar bodies (homoeomeres) which are not part of a compound of different parts (anhomoeomeres), and which are mineral bodies (metals) and specimens of mineral substances, and also the consideration of what is proper to each of their species and this is taught in the book entitled *The Minerals*.

The *De mineris* is a short text from Avicenna whose role in the Latin tradition we shall study later. In this last quarter of the twelfth century, Daniel of Morley adopts from Gundisalvo the enumeration of the eight particular sciences, adding some examples, but in order to turn them into eight parts for astronomy i.e. of astrology.[84] In the case of alchemy this integration is reasonable: the *De perfecto magisterio* defines alchemy as 'an inferior astronomy'.[85] Daniel seems to know an alchemical treatise entitled *Lumen luminum*.[86]

The major problem of Arabo-Latin alchemy will be its compatibility with the new Aristotle. At the end of book III of *Meteorologica*, Aristotle promises a detailed exposition about metals and non-metal minerals. This plan is not carried out in the actual book IV, a treatise originally independent and added to the *Meteorologica* by the Greek tradition. The texts of Theophrastus, which fill the gap, remained unknown in the Latin culture of the Middle Ages. Book IV had been translated from Greek in 1156 by Henry Aristippus, archdeacon of Catania.[87] In the following decades, Gerard of Cremona had put into Latin the Arabic translation from Yaḥyā ibn al-Biṭrīq, but he stopped at the beginning of book IV.[88] Around 1200, Alfred the Englishman, first commentator of the *Meteorologica*,[89] aware of the inadequacies of the text, adds at the end three chapters entitled *De mineralibus* which will accompany the *Meteorologica* in all the manuscripts of the *translatio vetus* and will be thought to represent, until the sixteenth century, the thoughts of Stagirite himself.

These chapters are a summarized translation from a section of *Kitāb al-Shifā'* by Avicenna.[90] They concern the formation of stones, the origin of mountains and the classification of minerals (liquifiable stones, sulphurs, salts), but also the origin of the metals. Basing himself on the alchemical tradition, Avicenna explains there that the metals result from the union of mercury with sulphurous earth, i.e. as we know, from a fusible component and a combustible or oxidizable component.[91] According to the quality of the constituents and the intimacy of the mixture, the metals will be more and more noble. But, as art is weaker then nature, the *artifices alkimie* are certainly capable of stripping base metals of their impurities, colour, taste, sound, but they will only perform an approximate transmutation. A real transmutation can only be achieved by modifying the elemental composition, i.e. by reducing the base metals to their primary constituents.[92]

This text is therefore not a pure critique of alchemy as its opponents have claimed since the Middle Ages. Setting aside the methods of the workers without philosophy, the Aristotelian text augmented in this way opens the door wide to the use of alchemical texts in scholastic philosophy.

One of the first meetings between alchemy and Aristotelianism occurs in the collection known by the name of *Questiones Nicolai Peripatetici* which Albert the Great attributes to Michael Scot.[93] Written before 1230, it is the work of a curious spirit, well informed, and of the *Meteorologica* and the *De Mineralibus* of Avicenna. He tries to give an account in Aristotelian terms of a great number of phenomena produced by alchemical procedures: sublimation and bleaching of orpiment and sulphur,[94] distillation of wine and the production of alcohol,[95] hardening or softening of metals,[96] transmutation. Often he completes the Stagirite by ingenious corpuscular reflections.

The problem becomes complicated by the fact that there existed at the same time some famous alchemical treatises passing as Aristotle's work, e.g. the *De perfecto magisterio*, and at least two treatises from Avicenna, the *Epistola ad Hasen regem* and the *De anima in arte alchimiae* of which the first has some chance of being authentic.[97]

The lapidary phrase *sciant artifices alkimie species transmutari non posse* will be passionately discussed until the sixteenth century. The actors are in place for the scholastic debate about the validity of alchemy.

## CONCLUSION: THE ARABIC CONTRIBUTION

At the threshold of his major study of Rāzī, Julius Ruska wrote:[98] 'We can never stress enough that the alchemy of the Latin West owes nothing to the Greeks; to the Arabs it owes more or less everything. For decades we have persisted in studying fragments from the Greek alchemists as if the contents and essence of Latin alchemy could be explained by it. ... It was not the Greek alchemists but the translations from original Arabic works which paved the way for Western development.'

In fact the Western Middle Ages have always recognized their debt to the Arabs. The real and false Jābir, often called 'king of the Arabs', Rāzī, Avicenna and Senior Zadith (Ibn Umayl) passed as princes in this art, and the Latins tried hard to follow their path. It is only with the Renaissance that the Arabs will see themselves reduced to the role of Greek interpreters.

This admiration entailed a proliferation of 'in the way of', perpetuating a style stemming from artificial Arabisms. Such is the *Declaratio lapidis physici Avicennae filio suo Aboali.*[99] Such also is the *Summa perfectionis magisterii* from Geber, which Berthelot had already shown could not be from Jābir.[100] Discovering its real author, Paulus of Taranto, William Newman identified him as the last interpolator of the *Secrets* from Rāzī, showing in this way his continuity.[101]

This continuity often hinders the ability to distinguish, amongst the words, substances, devices, procedures and concepts, those which come from the imputation and exploitation, in Europe, of imported materials. The borrowed word *alkohol* designates in its origin the powder of antimony, but it is only with Paracelsus that it takes today's meaning. As for the *alkahest* of Van Helmont, only the article is Arabic. The distillation device was introduced in the twelfth century, through both alchemic and medical translations, but its two main applications, the water of life and mineral acids, seem to be European innovations which slowly extricate themselves from a jumble of plant extracts, incendiary compositions and corrosive liquids. In the doctrines, the theory that sees metals as a combination of an oxidizable or combustible component, sulphur, and of a fusible component, mercury, is doubtful Greek alchemy and appeared for the first time in the book of Balīnās. But it is difficult to establish its filiation in the ingenious systems which try hard to reconcile this basic intuition with Aristotle and the laboratory. From Balīnās to Paracelsus, only one tradition develops without fracture. In the seventeenth century, the work of Paracelsus and his disciples will itself be put into Arabic in Egypt.

## NOTES

1 The more complete repertories are those of Ullmann (1972) and Sezgin IV. But several interesting and not yet explored trails are suggested by Steinschneider.

2 On this literature see Cézard (1944, 1945).

3 See Halleux and Meyvaert (1987).

4 Scholy to Adam of Bremen, *Monumenta Germaniae Historica*, SS, VII, 349, or *Patrologie Latine*, 146, cols 583–4.

5 On the alchemical activities of Psellos (1018–98?), see Bidez (1928). We can even suppose that collection B from the Greek alchemists (BN Greek 2325), prefaced with a letter from Psellos, represents a selection elaborated in his ambience.
6 Cf. Theophilus, III, 48.
7 Translation C. R. Dodwell.
8 The word does not appear, however, in the list published by Siggel.
9 See for instance Johnson (*Lexicon*) and Manget (*Bibliotheca*: 262): 'Sanguis hominis rufi: sulphur mercurius solis'.
10 See MacCulloch (1960: 93) and Ansell Robin (1932: 86–91).
11 C. Opsomer and R. Halleux (1994) 'L'alchimie de Théophile et l'abbaye de Stavelot', in *Comprendre et maîtriser la nature au moyen âge. Mélanges d'histoire des sciences offerts à Guy Beaujouan*, Genoa, Paris, pp. 436–59.
12 See Clagett, article 'Adelard of Bath', *Dictionary of Scientific Biography*, I, pp. 61–4.
13 On this manuscript, see Smith and Hawthorne (1974: 5–7).
14 According to Berthelot (1906), it concerns recipes 195–200. However, recipe 201 has the words 'natroni, id est alatroni', and recipes 202 and 203 the words 'natroni' and 'borax', which are Arabic.
15 See Warner and Gilson (1921: 165).
16 See Berthelot (1906).
17 Text of the Arabic original partially published after BN lat. 6514, folios 41–51, by Berthelot (1893: I, pp. 179–228). See on this subject Ruska (1936). Corrections and supplementary recipes further on in the same manuscript were published by Corbett (1939: 294–309).
18 See Scot, (1938: 527, no. 50).
19 See Steinschneider, (1956: I, p. 72, d; II, pp. 81 and 107).
20 See Schipperges (1964: 152) and Ploss *et al.* (1970: trad. fr. p. 83).
21 See Theophilus, pp. lxvii–lxviii.
22 See *Morienus*, in Manget (*Bibliotheca*: 519): 'Explicit liber alchymiae de arabico in latinum translatus anno millesimo centesimo octuagesimo secondo, in mense februario et in ejus die undecimo.' On Robert and the world of the translators, see the excellent report in Burnett (1982).
23 See Ruska (1924) and Ullmann (1978a); this last work is essentially based on the arguments *a silentio*.
24 See Reitzenstein, with the comments of Ruska (1937a: especially p. 27).
25 See Ruska (1928).
26 See Stavenhagen (1970).
27 See *Morienus*, in Manget (*Bibliotheca*: 509): 'Cum et hoc genus docendi in hujus libri divini translatione non suscepimus, nec etiam nostri ingenii tenuitas aut studium vel scribendi negotium, vobis ad hoc explicandum possint sufficere. Sed idcirco eius nomen (sc. Hermetis) in huius libri prologo introduximus quoniam iam ille hunc librum primus invenit et edidit. His est namque liber divinus, et divinitate plenissimus (. . .). Si quis namque in hoc libro multum studueri et eum plenarie intellexerit, veritas virtusque testamenti nec non et utriusque vitae modus, et sufficienter illum latere non potuerunt (. . .). Sed nos,

licet in nobis juvene sit ingenium et latinitas permodica, hoc tamen tantum ac tam magnum opus ad transferendum de arabico in latinum suscepimus. Nomen autem meum in principio prologi taceri non placuit, ne aliquis hunc nostrum laborem sibi assumeret, et etiam ejus laudem et meritum sibi quasi proprium vindicaret.

28 See Silverstein (1955).
29 See *Morienus*, in Manget (*Bibliotheca*: 509).
30 See on this subject Weisser (1980) (with the preceding literature).
31 Preserved in BN lat. 13951 (c. XII); only fragments were published by Nau. On the translators see Burnett (1977: especially pp. 62–76).
32 See Steele and Singer (1927).
33 *Ibid.*, p. 498, lines 20–1; 'Potens namque Spiritus Sanctus qui dividit singulis prout vult, in verba eadem interpretanda, intellectum faciliorem in minoribus tribuens'.
34 See Waley Singer (1928: 25) (Cambridge University Library LI–III–17 folios 115–134v).
35 See Sudhoff (1914: 79).
36 Partial edition of the Arabic text in Kraus (1935) translated into French by P. Lory (1983). The fundamental study is that of Kraus (1943) with a more recent bibliography from Sezgin IV, pp. 14–16.
37 See Berthelot (1906), *Archéologie et histoire des sciences*, pp. 310–63: 'Liber de septuaginta translatus a magistro renaldo cremonensi de lapide animali'.
38 See Darmstaedter (1925a).
39 On the course of publication by M. William Newman.
40 See Ruska (1935b).
41 See Darmstaedter (1925b).
42 He, amongst others, is largely exploited by Vincent of Beauvais in his *Speculum naturale*, for example in VII, 38, 54, 62 etc.
43 See Sudhoff (1914: 79, no. 67).
44 For instance, there is one *Lumen luminum ex libris medicorum* attributed to Rāzī (TK 833), one *Lumen luminum* from Brother Elias of Cortona (TK 732) and one other from Michael Scot (Incipit *Cum rimarer*, TK 336, see below).
45 For example BN lat. 6514, folios 113–120v: 'Liber Raxis qui dicitur lumen luminum magnum'.
46 Kues 299, f. 96v: 'Explicit theotorica occultorum ramundi civis massiliensis a caldeo in latinum translata'.
47 *De perfecto magisterio*, in Manget (*Bibliotheca*: 639): 'Secundum quod in quodam opere meo habetur, quod Lumen luminum inscribitur'.
48 Note that Ruska (1939: 45) dates it from the thirteenth century. But it is the last state of a text which has not stopped evolving.
49 See Arnold of Saxony. The chapters taken from *Lapidary* were edited by Rose (1875: 425–6, paras 20–7.
50 See Halleux (1982).
51 See Ruska (1912).
52 *Ibid.*, pp. 38–41.
53 See Rose (1905).

54 See Ganzenmüller (1955: 360–5).

55 We could not find it in the Latin texts supposedly from Artephius. This author, much appreciated by Roger Bacon, has been identified without due consideration with the vizir and alchemist al-Ṭughrā'ī (1060–1120). See Chevreul, Austin and Levi della Vida.

56 The *De anima in arte alchemiae*, Pseudo-Avicennian, very much used by Bacon, was one of the last texts to be translated. In fact, the explicit of the *dictio X* gives the date as 1235.

57 See note 52 above.

58 See Albert the Great, *De mineralibus*, III, I, 4, p. 64 from the Borgnet edition.

59 The *De lapide philosophorum* is in the *Theatrum chemicum*, III, pp. 143–51; the *Thesaurus philosophiae*, *ibid.*, pp. 151–65. The Arabic sources are innumerable but seem to be used in their Latin translations. The last treatise, p. 154, quotes Raymond.

60 See Ruska (1935c; 1937b).

61 See *Artis Auriferae*, I, pp. 226–31. The *Liber secretorum alchemiae* (*ibid.*, pp. 208–25) has a lost Arabic model which is not previous to the eleventh century.

62 Edition in *Theatrum chemicum*, V, pp. 101–85. See Singer (1946).

63 See *Artis chemicae Principes*, I, pp. 1–471. On the forgery see the chapter by Anawati. According to the *dictio X*, the treatise would be from 1021.

64 The *Epistola ad Hasen regem* (in *Theatrum*, IV, pp. 863–74) is an important text. The Arabic original discovered in India in a manuscript from Lucknow has been published by Stapleton *et al.* The treatise was dedicated to Abū al-Ḥasan Sahl, sovereign of Gurganj between 997 and 1015. Ruska (1933) notes contradictions with the opinion of the *Kitāb al-shifā'* according to which alchemy is impossible. Stapleton says that it might belong to another period of his life. In reality, it lies on the same level of knowledge as the *Shifā'*, with the same theory about sulphur and mercury, and a classification of the minerals close to that of al-Rāzī. He already mentions a debate about the alchemists' pretentions.

65 The *Turba philosophorum* is probably the translation from the *Book of the Assembly* from 'Uthmān b. Suwayd al-Akhmīmī (around 900). In the form of a speech by Presocratic philosophers, it tries hard to combine alchemy, Greek philosophy and Islam. See Plessner (1975).

66 Ibn Umayl lived from 900 to 960. See on this subject Ruska (1934; 1935d). the text was published by Turāb ʿAlī *et al.*

67 See Holmyard (1926).

68 See Holmyard (1937).

69 Minio Paluello (art. 'Scot, Michael', *Dictionary of Scientific Biography*, IX, pp. 361–5) is not against the authenticity of the work.

70 See Scot (1938).

71 *Ibid.*, pp. 533, 539, 540, 544, 556. To pin down, pp. 539 and 542, the references to one 'Brother Elie' who could be Elias of Cortona, successor of Francis of Assisi, and p. 544, mention of the Jew 'magister Jacobus', who could be the translator Jacob Anatoli.

72 *Ibid.*, pp. 533 *et seq.*, the apothecary from Montpellier.

73 The two texts are published in parallel by Wood Brown (1897: 240–69). One source, the *Liber dabesi*, describing combustions and decompositions of organic substances, seems suitable for *Liber dedali.*

74 See Scot (1938: 532): 'Cum animadverterem nobilem scientiam apud latinos penitus denegatam vidi neminem ad perfectionem venire propter confusionem que in libris philosophorum reperitur'.

75 See Crisciani (1976).

76 On the spirit of these kinds of texts, see Halleux and Schamp (1985).

77 See Burnett (1982: 37).

78 *Ibid.*, 75 v F, 76 r A.

79 *Ibid.*, 75 v E, 75 v H.

80 *Ibid.*, 72 v DE.

81 *Ibid.*, 65 v C.

82 See Gundissalinus (1903: 20).

83 See al-Fārābī *Iḥṣā' al-ʿUlūm*, p. 32.

84 See Daniel of Morley, *Liber de naturis inferiorum et superiorum*, 158, p. 239 of the Maurach edition.

85 See Pseudo-Aristotle, *De perfecto magisterio*, in Manget (*Bibliotheca*: 638): 'Scias praeterea hanc artem vocari inferiorem astronomiam, et superiori primae est comparativa'.

86 See Daniel of Morley (note 87), p. 230: 'Licet enim philosophus in libro luminum aquam albidam nominaverit, non tamen nisi aquam elementatam intelligere dedit, et maluit forte in hoc a vulgo intelligi quam ipsam philosophiam imitari'. The distillation of a white water can be found in the *De perfecto magisterio*, in Manget (*Bibliotheca*: 649).

87 On this translator, who died in 1162, see Fobes (1915), Haskins (1927) and Minio Paluello (1947).

88 See Sudhoff (1914: 73). He probably translated the first chapter as it can be seen in BN lat. 6325, f. 107r. This text, already mentioned by Fobes, was edited by Lacombe (Aristotle: *Aristoteles Latinus*, pp. 134–5); cf. p. 57. On the Arabic–Latin translation, see Petraitis and Schoonheim.

89 See Otte (1972; 1976). Often the scribe does not even distinguish it from book IV. The treatise is found in the *Corpus recentius*. It can also exist by itself under the name of Avicenna or Aristotle.

90 See Holmyard and Mandeville (1927). This edition contains the Arabic text and a very incorrect version of the Latin translation. On these chapters see Baffioni (1980: especially pp. 90–6), with the translation from the Arabic text.

91 See the Latin version of the text from Avicenna in Holmyard and Mandeville (1927: 51).

92 Latin text from Avicenna in Holmyard and Mandeville (1927: 53–4): 'Ars est debilior natura et non consequitur eam quamvis multum laboret. Quare sciant artifices alkimie species metallorum mutare non posse sed similes facere possunt. (. . .) Hec compositio in aliam mutari non poterit compositionem nisi forte in primam reducantur materiam et sic in aliud quam primum erat permutatur. Hoc autem per solam liquefactionem non fit sed acciduntur ex hoc res quædam extranee'.

93 See the edition by S. Wielgus.

94 *Ibid.*, pp. 85, 86, 92.
95 *Ibid.*, pp. 95, 97, 114.
96 *Ibid.*, pp. 99, 100, 101, 103 etc.
97 See above, note 67.
98 See Ruska (1935c: 1).
99 See *Theatrum chemicum*, IV, pp. 875–82.
100 See Berthelot (1893: vol. I).
101 See Newman (1991).

# 27

# *Medicine*

EMILIE SAVAGE-SMITH

During a period of roughly nine centuries (from the middle of the eighth to the middle of the seventeenth centuries AD) and in lands as diverse as North Africa and Spain, Western India, the Anatolian peninsula, and the central areas lying between the river Nile and the river Oxus, it was inevitable that the practice of medieval Islamic medicine would show great variation and diversity. As ideas were dispersed in the Islamic lands, strands of shared traditions spanned vast areas and crossed many centuries. Communication over such a vast area during the course of several centuries was, as would be expected, neither uniform nor always very swift, and the dispersion of ideas and texts from one area to another was uneven and somewhat subject to chance.

The medical theories inherited particularly from the Hellenistic world supplied a thread of continuity and uniformity to professional, learned medical practice throughout these lands. Wound round this thread, however, were innumerable other factors and local conditions which produced considerable diversity. The institutions and policies responsible for dispensing medical care were subject to political and social fluctuations. The general health of the Islamic community and the consequent medical concerns and care were influenced by many factors: the dietary and fasting laws and the general rules for hygiene and burying the dead of the different religious communities of Muslims, Jews, Christians, Zoroastrians and others; the climatic conditions of the desert, marsh, mountain and littoral communities; the different living conditions of nomadic, rural and urban populations; local economic conditions and agricultural successes or failures; the amount of travel undertaken for commerce, for attendance at courts, or as a pilgrimage; the maintenance of a slave class and slave trade; the injuries and diseases attendant upon army camps and battles; and the incidence of plague and other epidemics as well as the occurrence of endemic conditions such as trachoma and other eye diseases.

Medical care is, in addition, always multifaceted, with the needs of the society being served by various local traditional practices as well as the formal learned medicine. The sophisticated, learned medical texts represent only one facet of the actual medical care of the society. Furthermore, it is most difficult for us at this distance to know to what extent and frequency the ideas expressed in such treatises were actually carried out. Only in the instances where we have recorded case histories do we get a glimpse into the actual medical care. The medical practices of the society varied, not only according to time and place, but at the various strata comprising the society. The economic and social level of the patient determined to a large extent the type of care sought, and the expectations of the patients varied as did the approaches of the medical practitioners. Throughout medieval Islamic society a medical pluralism existed which may be viewed as a continuum running from the formal Greco-Roman theories and practices to those of local custom and magic.[1] Magical means and religious measures, as well as formal medicine, are all reactions to disease and legitimate attempts of the society to deal with it. A modern reader should not approach medieval Islamic medicine with an attitude of amused indulgence or contempt, nor should one hunt the present in the past.

The medical care in the Islamic lands involved a rich mixture of religions and languages to be seen in both the physicians and the patients – a coexistence and blending of traditions probably unrivaled in contemporaneous societies. Only two types of medical writing, the treatises on prophetic medicine and the plague tracts, reflected a distinctly Muslim approach. The Hellenistic medical teachings at Alexandria, apparently still an active medical community during the early years of the Islamic era, were welcomed and valued by an emerging nation and world power which needed to find ways of dealing with medical problems common to all peoples: disease, pain, injuries and successful childbearing. This heritage of medical theory and practice, mingled with some Persian, Indian and Arab elements, was assimilated and elaborated, with a persistent effort to make it more pertinent and useful, by a community of both Muslim and non-Muslim physicians speaking many languages – Arabic, Persian, Syriac, Hebrew and Turkish, though Arabic became the lingua franca and Islam the dominant faith.

## SOURCES

To assess the development of medical practice in the medieval Islamic world a wide variety of sources needs to be surveyed. For the ideas and practices of formally trained physicians, the major source are the very large number of medical treatises, both general and specialized tracts, which are preserved in manuscript form in libraries throughout the world. A good many of these, particularly writings prior to the seventh/thirteenth century, have been published and are available to European readers through one or more translations. None the less, some of the most important sources from the fourth/tenth and fifth/eleventh centuries, probably because of their enormous size, are still unavailable or at best not easily accessible. The literature from the seventh/thirteenth century and later is only now beginning to be scrutinized.

These medical writings can be supplemented with other written sources. Biographical dictionaries of learned men constituted a popular form of literature in the Islamic world and frequently included physicians; some, indeed, were concerned solely with physicians. While the lists of writings by physicians and the basic biographical data in these registers are a reliable and important source, they also present considerable anecdotal evidence which, while it is of interest for displaying social attitudes, concerns and biases, cannot always be taken unquestionably as documentary evidence for specific practices. Furthermore, the literary conventions of the genre and the fondness for success stories make this material difficult to use to obtain a full picture of the medical practice of the period.

Early Islamic physicians were themselves interested in the lives of physicians viewed as ancient to them, that is to say the Greek physicians, and they continued a late Greek tradition of establishing chronologies of early physicians. One such chronology of ancient Greek doctors was written in the third/ninth century by the Syrian Christian Isḥāq, the son of the foremost translator–physician Ḥunayn. This chronology introduces us to the difficulties which the early Islamic physicians faced when they tried to look back upon the development of their profession in an earlier society. Like others, Isḥāq ibn Ḥunayn resorted to the literary device of tracing the origins of practices back to mythical or religious figures or using such figures as chronological signposts.

Other written sources can also be pertinent; for example, the general histories and chronologies of a realm or dynasty, comprehensive encyclopedias containing sections of medical topics and travel literature. Both belles-lettres and a genre of literature termed *adab*, concerned specifically with manners and ethics of society, on occasion discussed physicians. Philosophical writings frequently dealt with medical topics, and theological and juridical opinions regarding medicine and the practice of physicians were of great importance. The records of the Prophet Muḥammad's reputed sayings and deeds, compiled mostly in the third/ninth century in a body of literature called *ḥadīths*, contain many statements on health and illness.

Documents related to the establishment of charitable trusts, or *waqfs*, by which hospitals and other public foundations were funded, are invaluable sources on medical practices, as are tracts outlining the regulations of water supplies, sanitation and fraudulent practices in market places.

Indirect, non-written sources can also give evidence of the medical concerns of a society. Archaeological excavations can reveal the design of hospitals or the sanitation system of a town and palaeopathology the incidence of certain diseases, injuries or surgical procedures. To date, however, only limited use has been made of such evidence. Unfortunately few medieval medical artefacts are extant, for it was not the custom, as it was in the Greco-Roman world, to include surgical instruments or stamps for drugs in graves. Only a small number of Islamic medical instruments made prior to AD 1800 are known to exist today. There are, however, a considerable number of artefacts such as amulets, magic bowls and instructions for making talismans and incantations, which were used by a large part of society in connection with their medical needs.

Another interesting, although not as informative, source are the illustrations accompanying some medical and pharmacological manuscripts. The fact that there was no general 'ban' on representing human figures in Islamic art is well illustrated by the medical texts. The interpretations of certain passages in the *Qur'ān* (such as V, 91) as restricting the depiction of human figures was applied only to religious texts and architecture. Secular buildings were occasionally decorated with human drawings; legends and romances were frequently highly illustrated; astronomical texts and instruments such as celestial globes depicted human constellation figures; and medical texts contained illustrations of humans. When detail was attempted, such as illustrating the anatomy of the eye or the arterial system, the result was highly schematic. Surgical instruments were usually illustrated without human figures, but when human figures were depicted in the process of a surgical procedure, the somewhat crudely delineated human figures dominate the picture while the procedures are only barely suggested, with few details evident. There are a number of miniatures in manuscripts giving portraits of physicians, while some illustrations show a physician teaching or several rival physicians. By and large the portraits of physicians provide little information on the medical practice itself and relatively little on the actual appearance of the early physicians, dominated as they are by artistic convention.

Although these sources appear varied and vast in terms of what one or even a group of scholars can today analyze and evaluate historically, they present only a small fraction of the complete picture of the medical practice occurring over nine centuries throughout the diverse Islamic lands. Our view of the medical practice in medieval Islamic society is necessarily limited by the sources we have, and these are dominated by learned treatises preserved somewhat by chance and not yet thoroughly studied by modern historians.

## MEDICINE BEFORE THE ʿABBĀSID CALIPHATE (PRIOR TO 132/749)

There were certainly medical concerns in pre-Islamic Arabia, as in any society, and practitioners who tended in some way the needs of the sick and the injured. The practices of this time appear to have continued as the dominate form of care throughout the Prophet Muḥammad's days and into the early days of the Umayyad caliphate. The nature of this medical care we know only from accounts of the sayings of the Prophet and others in the early Islamic community, as well as a few other fragmentary sources. However, since neither the Prophet nor those around him were concerned with describing in detail the medicine of the day, we have only a very incomplete picture.

The eighth/fourteenth-century historian Ibn Khaldūn had the following to say regarding these early practices which he saw reflected in the traditional medical ways of the urbanized Bedouins of his day:[2]

> Peasants among the settled people (*al-bādiya min ahl al-ʿumrān*) have a kind of medicine which is based for the most part upon experience confined to a few individuals. They pass it on as an inheritance from the *shaykhs* and old women of the tribe. Some of it may occasionally be correct. However, it is not based upon any natural principle (*qānūn ṭabīʿī*) or upon conformity to the temperament [*mizāj*, a reference to the Greek humoral system introduced later]. Much of this sort of medicine existed among the Arabs ... The medicine mentioned in religious tradition [concerned with Muḥammad] is of this type. It is in no way part of divine revelation. On the contrary, it is a matter of Arab custom and happened to be mentioned in connection with the circumstances of the Prophet, like other things that were customary in his generation.

It is evident that the digestive system and its disorders were the central concern, and diet the focus of both prevention and therapy; fevers were the main manifestation of disease. Protection from the evil eye and the use of talismans and amulets to aid in childbirth or ward off disease figure prominently. Wise women and elders were probably the main dispensers of the aid. Bleeding, scarification, and cauterization were performed, but surgery was not a part of the therapeutics.

Some 956 years separated the deaths of Alexander the Great and the Prophet Muḥammad. During this time the Greco-Roman system of medicine had developed, based primarily on the writings of Hippocrates, Galen and Dioscorides. Alexandria, as well as Rome, Constantinople, Antioch, Edessa and Amida, flourished as a centre of scientific and medical activity. A combination of political and religious events caused many Greek and Syriac-speaking scholars to move eastward to Persia and to establish centres of learning there. In AD 489 the Roman emperor closed the school at Edessa, and the learned men, mostly Christians of the heretical sect of Nestorians, took refuge in Nisibis in Persia, taking with them Greek texts and Syriac translations and epitomes.

The city of Gundīshāpūr, near the present-day village of Shāhābad in southwest Iran, also became a centre of learning in the sixth century AD, blending many languages and cultures – Greek, Syriac, Persian, Hindu, and Jewish. Historians have customarily asserted that Gundīshāpūr had an important hospital and medical school which supported the translation of Greek and possibly Sanskrit texts into Middle Persian and Syriac. The crucial role played by Gundīshāpūr in the development of hospitals and medical teaching in the Islamic world has recently been challenged by historians. There is in fact no evidence that there was a hospital in Gundīshāpūr or that scholars forced to leave Edessa settled there, as some have suggested. There may well have been a modest infirmary where Greco-Roman medicine was practiced and a forum where medical texts could be read, as was the case in other towns such as Susa nearby to the west.

The alleged prominence of Gundīshāpūr as a medical centre and hospital was probably due to the dominance of Nestorian Christians among the early physicians and translators of medical works at the Islamic courts. They may well have wished to claim the hospital as their idea and to establish a history to support their medical authority. Certainly the Nestorian monopolization of early medicine in Baghdād meant that the medicine they advocated, based upon Greek texts, was promoted over the rival practices of the Zorastrians or Indians and the native medicine of Arabia.

The sources tell us nothing about medical care extended to the four Orthodox caliphs (11–40/632–61), that is the first four successors to the Prophet Muḥammad, and little about medical care outside the court. There is the story of an Arab by the name of al-Ḥārith ibn Kalada, who is said to have been a relation of the Prophet Muḥammad and to have studied medicine at Gundīshāpūr. He was said to have had learned discussions with the Sāsānian ruler Khusraw Anūshīrawān, who died in AD 579, and to have lived until the time of the first Umayyad caliph (reg. 40–60/661–80). The accounts of al-Ḥārith ibn Kalada include many incongruous and legendary elements, so that it is difficult to assess the historical figure. We have the name of one other physician contemporary with Muḥammad, that of Ibn Abī Rimtha, who was supposed to have practiced surgery, having removed a mole from between Muḥammad's shoulders. Again, however, the account is of questionable authenticity.

A few meagre details emerge regarding the physicians serving the early Umayyad caliphs. The first Umayyad caliph, Muʿāwiya, employed the physician Ibn Uthāl, a Christian of Damascus. The grandson of Muʿāwiya, Khālid ibn Yazīd (d. 85/704), who did not succeed to the caliphate, is said to have had medical, alchemical and astrological books translated into Arabic for his own use. Many legends, especially associated with alchemy, were attributed to him by later writers.

The physician to the caliph ʿUmar ibn ʿAbd al-ʿAzīz (reg. 99–101/717–20) was ʿAbd al-Malik ibn Abjar al-Kinānī, a convert to Islam who it is reported had studied at the surviving medical school in Alexandria. For this same caliph it is said that a Persian Jewish physician living in Baṣra by the name of Māsarjawayh, or Māsarjīs, translated from Syriac into Arabic a medical handbook that had been written by Aaron the Priest (Ahrūn al-Qass) a century earlier in Alexandria. Other accounts have Māsarjawayh living at the beginning of the ninth century AD.

There is also a report of medical treatment just prior to the reign of the Umayyad caliph al-Walīd I, who ruled from 86/705 to 96/715. The third/ninth-century poet Ibn Qutayba gives a brief account of ʿUrwa ibn al-Zubayr of Medina (d. 94/712), who was a legal authority. Ibn Qutayba records that in the year before al-Walīd was made caliph, ʿUrwa 'suffered from gangrene (*al-ikla*) in his foot while in Syria with al-Walīd ibn ʿAbd al-Malik [soon to be al-Walīd I]. They cut off his foot while al-Walīd was present. But he was completely still, and al-Walīd did not realize that it had been cut off until it was cauterized and the odor of the cautery was evident. After that ʿUrwa lived eight years.'[3]

By the next century the account had been elaborated to the point where al-Iṣbahānī (d. 356/967) says that ʿUrwa was offered a drug to drink so he would not feel the pain, but that he refused it as being beneath his dignity. In the sixth/twelfth century the Baghdād theologian and historian Ibn al-Jawzī says that ʿUrwa was not only offered a soporific (*muraqqid*) to drink, but that after the amputation he took the leg from the hands of the physicians and, addressing the leg, said: 'What makes me feel good about you is that I never moved you to disobey God.'[4]

The changing accounts of the amputation of ʿUrwa's leg illustrate the difficulties for the medical historian inherent in early reports, for they were recorded to illustrate other points, in this case dignity and piety. Details of the medical care are obscure and conflicting. What is certain is that later generations viewed the Umayyad court as supporting more than one physician capable of performing amputations and giving a soporific to relieve pain.

Our sources for this entire period are fragmentary, conflicting, and therefore questionable. The Umayyad rulers were preoccupied with extending and defining Islamic lands, and the requirements of the rapidly expanding government and the burgeoning theocracy probably did not permit a great deal of attention to be given to social problems or scholarly enterprises. It is not impossible that the Umayyad court supported people who had some connection with Byzantine medicine as practiced in Alexandria or in Gundīshāpūr. It is quite likely, however, that the pre-Islamic Bedouin customs of treatment, whatever that might have involved, prevailed even among the settled Arabs and the emerging urban society well into the third/ninth century, when Greco-Roman and Byzantine theories and practices were thoroughly assimilated by the educated élite of Islamic medical practitioners.

## EARLY ʿABBĀSID MEDICINE

After normalization of the political situation in the middle of the second/eighth century, the cultural and social contacts with the recently annexed and neighbouring lands increased and stabilized. The translation of scientific and philosophical works from the older cultures was undertaken on a major scale after the ʿAbbāsid caliphs moved the location of the court from Damascus to Baghdād.

The caliphs al-Manṣūr, Hārūn al-Rashīd and al-Maʾmūn are noted for their patronage of learning and for bringing physicians from nearby Gundīshāpūr to Baghdād. When suffering from a stomach complaint, al-Manṣūr (reg. 136–58/754–75) called Jurjīs ibn Jibrāʾīl ibn Bakhtīshūʿ to Baghdād from Gundīshāpūr, where he had been the leading physician. This physician, who wrote a medical handbook in Syriac, eventually returned to Gundīshāpūr, where he died after 151/768. His son was also called in 171/787 to Baghdād, where he remained until his death in 185/801, serving as physician to the caliph Hārūn al-Rashīd. The third generation of this family, Jibrāʾīl ibn Bakhtīshūʿ, was physician to Hārūn al-Rashīd and to the two succeeding caliphs in Baghdād. For eight generations, well into the second half of the eleventh century AD, twelve members of the Bakhtīshūʿ family of Nestorian Christians were to serve the caliphs as physicians and advisors, to sponsor the translation of texts and to compose their own original treatises. A remarkable if not unique record in the history of medicine.

Early in the third/ninth century, there was established in Baghdād a foundation called the House of Wisdom (*bayt al-ḥikma*), which had its own library. Its purpose was to promote the translation of scientific texts, and an embassy was sent to Constantinople to acquire such material. Placed at the head of this institution was a Nestorian Christian by the name of Yūḥannā ibn Māsawayh (d. 243/857), whose father had been a physician in

Gundīshāpūr before coming to Baghdād. He is best known for the quite considerable number of treatises of his own composition. His writings included a medical handbook which is the first to present the material in a diagrammatic format and treatises on fevers, leprosy, poisons, melancholy, headaches, eye diseases, diatetics, examining physicians and a collection of medical aphorisms. It is evident from his writings that certain diseases, such as an eye condition known today as pannus, were recognized and clearly described, even though they were not to be found in the earlier Byzantine sources. It was reported that Ibn Māsawayh regularly held a *majlis* or assembly of some sort, where he discussed subjects with pupils and consulted with patients. At times he apparently attracted considerable audiences, having acquired a reputation for repartee.

The most famous of his pupils was Ḥunayn ibn Isḥāq al-ʿIbādī, another Nestorian Christian but originally from al-Ḥīra in southern Iraq. While an author of many medical tracts and a physician to the caliph al-Mutawakkil (reg. 232–47/847–61), he is most famous as a translator. Ḥunayn began translating at the age of seventeen under the direction of Ibn Māsawayh, and he produced a truly prodigious amount of work before his death about 260/873. He translated into Syriac or Arabic nearly all the Greek medical books known at that time, half of the Aristotelian writings as well as commentaries, various mathematical treatises and even the *Septuagint*. Ten years before his death he recorded that, of Galen's works alone, he had made ninety-five Syriac and thirty-four Arabic versions. Ḥunayn's pupils, including one of his sons and a nephew, used his Syriac versions for making later Arabic ones. Accuracy and sensitivity were hallmarks of his translating style, and he was no doubt responsible, more than any other single person, for the establishment of the classical Arabic scientific and medical vocabulary. Of Ḥunayn's original writings, his treatise entitled *Questions on Medicine for Students* (*al-Masāʾil fī al-ṭibb li-l-mutaʿallimīn*) was very influential, along with *Ten Treatises on the Eye* (*Kitāb al-ʿAshr maqālāt fī al-ʿayn*) and a variety of small tracts.

These and other translators, such as Thābit ibn Qurra (d. 288/901) who was a member of the pagan Ṣābiʾan sect of Ḥarrān in northern Mesopotamia, had access to the court as advisors and learned men, regardless of their religion or race. Through these translations a continuity of ideas was maintained between Alexandrian and Byzantine practices and Islamic medicine.

In addition to those men who were translators as well as physicians, there were a number of early physicians who are not known to have made translations themselves, but whose writings reflect the very early period of assimilation of foreign material. Foremost among this group is ʿAlī ibn Sahl

Rabbān al-Ṭabarī, son of a Christian scholar of Marw, south of the Caspian Sea. His book entitled *Paradise of Wisdom* (*Firdaws al-ḥikma*) was dedicated in 235/850 to the caliph al-Mutawakkil. ʿAlī ibn Sahl Rabbān not only summarized Greco-Roman and Byzantine practices in this compendium of medicine, but devoted a separate chapter to Indian medicine with the purpose of comparing it with the Greek. The author converted from Christianity to Islam, and before he died, not long after 240/855, he wrote two polemical books defending Islam against Christianity, Judaism, Hinduism and Zoroastrianism.

We know of roughly twenty-eight other physicians who practiced before the time of al-Rāzī (b. 251/865), the most important being possibly Qusṭā ibn Lūqā al-Baʿalbakī, who was a translator as well as author in his own right. Among his medical writings were books on the causes of the difference between men regarding their characters, modes of life, desires and preferences; on hygiene and diet for the traveller; on the plague and its causes; on infection (*iʿdāʾ*); on protection against rheum and catarrh which occur in the winter; on blood; on phlegm; on yellow bile; on black bile; on bloodletting; and on questions regarding the crisis of an illness.

Thus by the end of the third/ninth century the humoral system of pathology as outlined by the Greco-Roman physician Galen in the second century AD had been completely accepted and integrated into the learned medical thinking of the day. The Hippocratic writings of the fourth century BC, while extensively used by some Islamic physicians, were not in general as direct a formative influence on Islamic medicine as the Galenic writings. This system of pathology was based upon the notion of four humors – blood, phlegm, yellow bile, and black bile – derived from the earlier Hippocratic writings. Parallels were drawn with the four elements (air, water, fire, earth), while the four qualities were aligned in pairs with the humors in the following manner: blood hot and moist, phlegm cold and moist, yellow bile hot and dry, black bile cold and dry. The four seasons of the year were important, and climatic and geographical conditions were also considered significant.

Perhaps the admiration which Galen and later Byzantine and Islamic writers felt for schematism and symmetry encouraged them to maintain this four-part system even when it functioned rather awkwardly. When the humors were in balance (*eukrasia* in Greek and *iʿtidāl al-mizāj* in Arabic) a state of health existed, although it was recognized that a true equilibrium never exists in a person. One humor always dominated to some extent – hence the four parallel basic dispositions of men: sanguine, phlegmatic, choleric or bilious and melancholic. The individual temperament was further defined into nine types by the quality, or pairs of qualities, or ideal equilibrium, which predominated, subject to influence from external factors. When the combination of humors was disturbed from the normal state in an individual (*dyskrasia* in Greek and *khārij ʿan al-iʿtidāl* in Arabic), disease resulted. Some of the humors in such a state of morbidity must be either balanced by food or remedies possessing the opposite properties or got rid of from the body, hence the great stress on the use of purgatives, emetics and bleeding in the therapy. Proper regimen and diet were advocated to keep the factors in balance and maintain health.

This framework of pathology, which to us seems highly restrictive, did not prevent Galen and the later Islamic physicians who inherited the theory from carefully observing disease and employing logic to explain what they saw. Diagnostics and prognostics were of major concern to both Hellenistic and Islamic medicine, while the combination of philosophy and medicine which is so evident in the writings of Galen continued to be a part of medieval medical literature in Islam.

## THE GREAT SYSTEMATIZERS

Following the rather rapid assimilation of Greek, Persian and Indian medicine which occurred in the third/ninth century, Islamic writings became more systematic and synthetic, with an evident urge to produce the most comprehensive and complete medical reference work yet written. Organization of the vast body of knowledge into a logical and accessible format was a primary concern. Theoretical discourse on causes and symptoms expanded, but at the same time examples and procedures of an applied character were frequently introduced – a return perhaps to an outlook which was characteristic of Hellenistic times but had been lacking in the intervening Byzantine writings.

One of the greatest names in medieval Islamic medicine is that of Abū Bakr Muḥammad ibn Zakarīyā' al-Rāzī, Latinized as Rhazes, who was born in the Persian city of Rayy in 251/865 and died in the same town about 313/925. The historian of Islamic philosophy Richard Walzer has said the following of al-Rāzī:[5]

> Whenever we read a line written by al-Rāzī, we feel ourselves in the presence of a superior mind, of a man who is sure of his own value without being conceited, and who does not consider himself to be inferior in philosophy and medicine to his great Greek predecessors whom he admires as his masters. Although Socrates, Plato and Aristotle, Hippocrates and Galen can, in his view, not be surpassed, he does not hesitate either to modify their philosophical conclusions if he believes that he knows better, or to add to the store of accumulated medical knowledge what he has found out by his own research and observation. Whenever for instance he treats a particular disease he first summarizes everything he can find in Greek and Indian sources, now

available in Arabic translations, and in the works of the earliest Arabic doctors. He never fails to add his own opinions and his own judgment; he never adheres to authority as such.

Before learning medicine, he studied philosophy, alchemy and music. Some later criticized al-Rāzī for his Neoplatonic philosophy and his refusal to accept the principle of absolute authority; others accused him of heresy in his theological ideas and of leading men on erroneous courses and destroying their money through his advocacy of alchemy. He served at the Sāmānid court in Central Asia, and headed hospitals in Rayy and Baghdād. A story is related that he was instrumental in determining the location in Baghdād of the hospital founded by ʿAḍud al-Dawla, for he is said to have chosen its position by hanging pieces of meat in various quarters of the city and finding the quarter in which the putrefaction of the meat was the slowest. However, since the ʿAḍudī hospital was founded in 370/980, more than 50 years after al-Rāzī died, it must be an earlier hospital, probably the one founded during the reign of al-Muʿtaḍid (279–89/892–902), which he helped locate and of which he was later made director.

Best known of his writings is his *On Smallpox and Measles* (*Kitāb fī al-jadarī wa al-ḥaṣba*). This treatise is not the earliest monograph on the subject – that honor goes to Thābit ibn Qurra (d. 288/901), whose treatise has not yet been studied though a copy of it exists in Aleppo today. The treatise by al-Rāzī demonstrates quite well his concern for therapy, and its thoroughness stands in sharp contrast to the silence regarding the topic in the Hellenistic and Byzantine literature preserved today.[6] The following quotation illustrates his concern for protecting the cornea of the eye from pustules. Indeed until very recent times smallpox has been a major cause of blindness in the Middle East as well as elsewhere, for among its most frequent complications are corneal scars and the destruction of the cornea caused by the pustules. In this treatise al-Rāzī says the following:[7]

As soon as the symptoms of smallpox appear we must take special care of the eyes, then of the throat and afterwards of the nose, ears, and joints in the way I am about to describe. And besides these parts, sometimes it will be necessary for us to extend our care to the soles of the feet, and the palms of the hands, for occasionally severe pains occur in these parts from the eruption of smallpox in them being difficult on account of the hardness of the skin.

As soon as the symptoms of smallpox appear, drop rose-water into the eyes from time to time, and wash the face with cold water several times in the day, and sprinkle the eyes with the same. For if the disease is mild and the pustules few in number, you will by this method of treatment prevent their breaking out in the eyes. But this is only a precaution, because when the smallpox is mild and slight, it is unlikely that some of the disease matter (*mādda*) will break out in the eyes. On the other hand, when you see a vehement outbreak (*thawarān*) and a large number of [pustules] at the outset of the eruption, and the eyelids itch and the whites of the eyes are red, with some places very red indeed, then in those places it will certainly break out, unless very strong measures are adopted. So you should immediately drop into the eyes several times in the day rose-water in which sumach has been macerated. It will be still more effectual to dissolve galls in rose-water, and drop some of it into the eyes; or to drop into them some of the juice of the pulp of sour pomegranate, first chewed, or squeezed from a cloth. Then daub the eyelids with the collyrium (*shiyāf*) composed of horned poppy, unripe and sour grapes, sweet lycium, aloe, and acacia, of each one part, and a tenth part of saffron; and if you also drop some of this collyrium into the eyes, it will be useful at this time.

But if you see that the disease matter is potent, and the pox has a very extensive eruption and you conclude that it will certainly break out in the eyes, since you see excessive redness in some places of the white of the eyes, with protrusion of the eye itself; and you see that when you have dropped into it some of the remedies which I have prescribed, it does not altogether remove and destroy the redness, but only alleviates it for a time, after which it returns more violently than before, or it least to the same extent as it was before you began this treatment; in that case you must not put into the eye those things prescribed earlier, or anything similar, but instead drop into the eyes a little Nabatean garum,[8] in which there is absolutely no vinegar or acidity.

The pox which breaks out on the cornea obstructs the sight and is to be cured, according to the degree of its thickness or thinness, by means of the medicaments which forcefully dissolve, which we will discuss [further on]. And sometimes they are successful and sometimes not, the latter occurring when it [the pox] is thick or a person (*badan*) is stiff or aged. But if large poxes break out in the iris [? *sawāf*] of the eye, then rub a dry collyrium [*kuḥl*] in rose-water and drop it into the eye several times during the day, and put over it a bandage and compress; or else drop into it some of the previously mentioned collyrium, after taking out the saffron and adding one part haematite, that there may not occur any great protrusion. This is what is necessary to know concerning the eyes in this place.

Al-Rāzī wrote on many subjects besides medicine, including logic, philosophy and in defence of alchemy; his medical treatises, however, outnumber those on other topics. The *Book of Medicine Dedicated to Manṣūr* (*Kitāb al-Ṭibb al-Manṣūrī*) was a short general textbook of medicine of considerable influence, which he had dedicated in 290/903 to the Sāmānid prince Abū Ṣāliḥ al-Manṣūr ibn Isḥāq, governor of Rayy. Among his smaller medical tracts were treatises on colic, on stones in the kidney and bladder, on curing diseases in one hour (such as headache, toothache, haemorrhoids and dysentery in small children), on diseases of children, on diabetes, on food for the sick, on maladies of the joints, on medicine for one who is unattended by a physician, on medical aphorisms and on the fact that some mild diseases are more difficult to diagnose and treat than the serious ones. He also composed a book on the reason why the heads of people swell at the time of the roses and produce catarrh, in which he was apparently the first to relate hay fever to the scent of roses.

Of all his compositions, the most sought after was the *Kitāb al-Ḥāwī fī al-ṭibb* (*The Comprehensive Book on Medicine*). Rather than a formal treatise this was an enormous commonplace book into which he had placed extracts from earlier authors regarding diseases and therapy and also recorded clinical cases of his own experience. Following al-Rāzī's death, Ibn al-ʿAmīd, the statesman and scholar appointed vizier (*wazīr*) to the Persian Buwayhid ruler Rukn al-Dawla in 327/939, happened to be in Rayy and purchased from al-Rāzī's sister the notes comprising the *Ḥāwī*. He then arranged for the pupils of al-Rāzī to put the notes in order and make them available. The *Ḥāwī* is an extremely important source for knowledge of Greek, Indian and early Arabic writings now lost, for al-Rāzī was meticulous about crediting his sources. Moreover the clinical cases, while not unique, are the most numerous and varied in the Islamic medieval medical literature. The material comprising the *Ḥāwī* is arranged under the headings of different diseases, with separate sections on pharmacological topics.

Descriptions of particular cases treated by al-Rāzī are scattered throughout the *Ḥāwī*, but there are thirty-four such case notes grouped together, apparently with the intention that they be read alongside the case histories found in the Hippocratic book *Epidemics*. Two examples will follow. A case of what must be acute nephritis (acute glomerulonephritis) following measles is described as follows:[9]

> A man of the Banū Sawāda [a tribe] had a bilious fever in his throat.[10] In the morning of the fourth day he urinated blood and passed green bile along with bloody bile resembling water in which fresh meat had been washed, and his strength decreased suddenly. That baffled us, because his malady had been benign and mild and then had changed in one night to this acuteness and severity. We guessed that he had drunk something [harmful]. When the afternoon came, he urinated black urine and also passed black biles. He died in the early morning of the sixth day. He had had from the beginning a malign form of measles, prone to attack the internal organs.

Another example was recorded by al-Rāzī to illustrate the possible dangers of using medicaments which suppress coughing. The patient apparently suffered from tuberculosis of the lungs (phthisis).[11]

> There came to us the consumptive elder (*maslūl shaykh*). He had been repeatedly coughing up much blood over a long period of time. Then it became much more distressing for him, so he took hazelnuts with water which stopped

> the cough. He got relief each time he did it, and he [apparently] recovered completely. Then he died. I had been unable to examine his condition during these days. Consequently, one should avoid remedies which suppress expectoration, except in cases where the matter flows down from the head.

Elsewhere in the *Ḥāwī*, al-Rāzī mentions a method he used to determine which treatment was best for patients he thought might develop meningitis:[12]

> When the dullness (*thiqal*) and the pain in the head and neck continue for three and four and five days or more, and the vision shuns light, and watering of the eyes is abundant, yawning and stretching are great, insomnia is severe, and extreme exhaustion occurs, then the patient after that will progress to meningitis (*sirsām*) . . . If the dullness in the head is greater than the pain, and there is no insomnia, but rather sleep, then the fever will abate, but the throbbing will be immense but not frequent and he will progress into a stupor (*līthūrghas*). So when you see these symptoms, then proceed with bloodletting. For I once saved one group [of patients] by it, while I intentionally neglected [to bleed] another group. By doing that, I wished to reach a conclusion (*ra'y*). And so all of these [latter] contracted meningitis.

Though today we do not accept a relationship between the use of bloodletting and the avoidance of meningitis, the method employed by al-Rāzī of treating one group of patients in one way and a second group differently is most imaginative and foreshadows later experimental methods.

Throughout his writings, al-Rāzī displays a primary interest in therapeutics, lacking the concern of later writers for refining the classification of symptoms. He was not in such awe of Galen that he refrained from correcting him, but his criticism was in the areas of logic and clinical applications. For example,[13] he said that in his experience in hospitals in Baghdād and Rayy he had seen as many cases whose courses did not follow Galen's description of fevers as did. He also stated in regard to a certain urinary ailment that, while Galen had seen only three cases, he had seen hundreds and consequently knew more about it. While al-Rāzī was critical of specific points, one can only conclude that he considered the medical theory adequate for his purposes, for he displayed no interest in altering its theoretical foundations.

Although the *Ḥāwī* is an extraordinary collection of medical observations and extracts from previous authorities, it was not without its critics. ʿAlī ibn al-ʿAbbās al-Majūsī, who was born probably about the time of al-Rāzī's death, was from a Zoroastrian family from the Persian city of Ahwāz not far from Gundīshāpūr. He practiced medicine in Baghdād and served as physician to the Buwayhid ruler ʿAḍud al-Dawla Fanā Khusraw, founder of the ʿAḍudī hospital in Baghdād. It is to him that al-Majūsī dedicated his only treatise, *The Complete Book of the Medical Art*, also called *The*

*Royal Book* (*Kitāb Kāmil al-ṣināʿa al-ṭibbīya* or *al-Kitāb al-Malakī*). This is one of the most comprehensive and well-organized medical compendia of early medical literature.

Al-Majūsī begins with a critical survey of his sources, which consisted of seven authors: Hippocrates, Galen, Oribasius (AD 326–402) who was physician to Julian the Apostate, Paul of Aegina who wrote in Alexandria at the time of the Arab conquest in 21/642 and his contemporary Aaron the Priest, Yūḥannā ibn Sarābiyūn who about 259/873 wrote a Syriac handbook of medicine, and al-Rāzī. After discussing al-Rāzī's medical epitome dedicated to Manṣūr, al-Majūsī had the following to say regarding al-Rāzī's *Ḥāwī*:[14]

> As to his book which is known as the *Ḥāwī*, I found that he mentioned in it everything which the medical practitioners (*mutaṭabbibūn*) require concerning the maintenance of health and the treatment of diseases and afflictions by means of medicaments and diet, as well as the symptoms of these diseases. He did not fail to discuss anything which the student of this art required regarding the management of diseases and afflictions. However, he did not discuss in it any of the natural [physiological] matters, such as knowledge of the elements, temperaments, humors, and the anatomy of the parts, nor even treatment by surgery. And what he did include he did not discuss with organization and order nor according to one of the didactic methods. He did not divide it into discourses, sections, and chapters, as his knowledge and his skill in the art of medicine and the composition of books would lead one to expect. At the same time, I do not dispute his importance or deny his knowledge of the medical art, and his writing skill is excellent. What occurs to me, or what I surmise on the basis of what an analogy with his wisdom and expertise requires, is that regarding this book there are two possibilities.
>
> Either he compiled it and recorded in it everything he noted from the entire field of medical knowledge so as to be an *aide-mémoire* just for himself which he would consult, in old age or during senility and forgetfullness, for what was required in the maintenance of health and the treatment of diseases; or he was afraid of damage occurring to his library, and so he provided for the loss with this book. And thus his making abstracts of treatises [accounts for] the major portion of the enormous size.
>
> Or [the second possibility], because he would benefit mankind by it and he would have a good memorial after his death, he made notes of everything he studied, with an annotation so that he could refer to it and then classify it and organize it, and group together every topic with similar ones and place it in its section according to what was appropriate based on his knowledge of this art. And so in this way the book would be complete and perfect, but then obstacles prevented him from [doing] that and death came to him before he could finish it.
>
> If indeed it was this latter type of writing which occupied him, then he had protracted the discourse in it and made it long without any compelling need causing him to do so. As a result, most scholars have not been able to acquire

a copy of it, except for a few people of wealth and culture, for it is rarely found. That is because in the description of each disease, and its causes, symptoms and treatment, he recorded what every one of the ancient and modern physicians had said regarding that disease, from Hippocrates and Galen to Isḥāq ibn Ḥunayn [one of the sons of Ḥunayn ibn Isḥāq] and the ancient and modern physicians between them, and he did not omit anything which each of them said from that which he recorded in this book; and on this model all of the medical books would have been contained in this book of his. But you ought to know that the skillful and the experienced physicians are in agreement in their description of the characteristics of diseases, and their causes, symptoms and treatment, and there is no difference of opinion between them, except in greater or lesser emphasis or in some terminology, since the rules and methods they follow in the study of diseases and ailments and their causes and therapy are precisely the same. If this is so, then there is no need to reproduce the sayings of ancient and modern physicians and to repeat their statements, since each one of them advances [ideas] just like what the others put forward. . . .

So it was appropriate for him, but I do not censure him, that he restrict the quotations to a few and be satisfied with citing [only] what is necessary and taking as examples the ones excelling in learning, the most forceful with regard to the advancement in the art, the best written for description, and the fullest for personal experience (*tajriba*). So that by this, the book would be easier for one who wished to purchase it or copy it, and the book would not be long and of enormous size and so would have circulated among men and be frequently found. But wherever I have gone, I have not learned of any copy of it except among two individuals, who are people of culture, learning and wealth.

Thus it is evident that within 50 years after al-Rāzī's death, copies of this repository of medical knowledge were very hard to obtain because, according to al-Majūsī, it was excessively long and hence too expensive to have copied (the modern printed version is incomplete at twenty-three volumes). Having criticized al-Rāzī for quoting too many second-rate authors, for lack of proper organization and for not devoting enough attention to anatomy and surgery, al-Majūsī then proceeded to produce a model of organization and systematization.

Al-Majūsī divided his composition into two major books, one on theoretical principles and the other on practical aspects. Each book had ten chapters with divisions and subdivisions under these, in keeping with the elaborate organizational format typical of medieval Arabic writing. The chapters of the first, theoretical, book cover the following topics: (1) historical sources and general principles of elements, humors and mixtures of humors composing the different parts of the body; (2) anatomy of the homogeneous parts (bones, bloodvessels, cartilage, flesh, hair, nails, membranes etc.); (3) anatomy of the heterogeneous parts (muscles, brain, eyes, nose, lungs, heart, kidney, etc.); (4) the three faculties (natural, animal and psychical), causes of death, sense perception and the pneumata; (5) the six 'non-naturals', being air and winds, movement and rest, eating and drinking, sleeping and waking, evacuation and retention (including bathing and coitus) and emotions; (6) classification and causes of diseases; (7) symptoms of diseases and diagnosis from pulse, urine, fevers, sputum, saliva and perspiration; (8) visible external diseases, including fevers, tumors, those occurring superficially (smallpox, leprosy, scabies, itching, lice, etc.), external diseases specifically related to certain parts of the body, wounds and lesions, animal and insect bites and stings and poisons; (9) causes and symptoms of internal afflictions (headache, epilepsy, melancholy, eye diseases, ear diseases, digestive disorders, etc.); (10) warning signs of the onset of disease, of severe and lengthy illness, of death, of recovery and of the crisis of a disease.

The second, practical, book had ten chapters on the following topics: (1) the general principles of hygiene, dietetics, cosmetics and therapy; (2) therapy with simple drugs (*materia medica*); (3) the treatment of fevers and swellings; (4) treatment of skin diseases and burns, bites, and poisons; (5) therapy for diseases of the head, eyes, ears, nose and mouth; (6) therapy for diseases of the respiratory organs; (7) therapy for diseases of the digestive organs; (8) therapy for diseases of the genitalia and reproductive organs; (9) surgery (*ʿamal bi-l-yad*), including bloodletting, cautery, surgery of the parts in order (eyes, ears, nose, etc.), and the setting of fractures and dislocations; and (10) recipes for compound medicaments.

A contemporary of al-Majūsī, but working independently in the far western part of the Islamic lands, was Abū al-Qāsim Khalaf ibn al-ʿAbbās al-Zahrāwī, latinized as Abulcasis or Albucasis, who worked sometime in Córdoba during the reign of the Spanish Umayyad Amīr ʿAbd al-Raḥmān III al-Nāṣir from 300/912 to 350/961. Al-Zahrāwī also composed a major synthesis of medical knowledge available in his day. The large encyclopedia was titled *Kitāb al-Taṣrīf li-man ʿajiza ʿan al-taʾlīf*, a title rather difficult to translate but meaning the arrangement of medical knowledge for one who is not able to compile a book himself. Of the thirty books making up the *Taṣrīf*, the first is concerned with general principles (elements, humors, temperaments, anatomy), while the second, much larger than any of the other books, is concerned with the symptoms and treatment of 325 diseases discussed in sequence from head to foot. Except for the last book, all the rest are rather short and are concerned with some aspect of pharmacology or diet. The thirtieth book, a lengthy one, is devoted to surgery, divided into three parts on cautery, incisions and bloodletting, and bonesetting, with illustrations of the instruments. This last book was very influential and circulated by itself, apart from the rest of the encyclopedia.

A Turkish version of it was prepared in 869/1465 for the Ottoman ruler Muḥammad II Fātiḥ (Mehmet the Conqueror) who had captured Constantinople 12 years earlier.

The major source for the surgery in the *Taṣrīf* was the Greek medical encyclopedia written in Alexandria by Paul of Aegina in the middle of the seventh century AD, which was accessible through an Arabic translation. Despite the essentially derivative nature of his compilation, al-Zahrāwī frequently inserted into the work his own observations and opinions. It has been suggested[15] that al-Zahrāwī shows much dependence upon the *Ḥāwī* of al-Rāzī, even more than upon Paul of Aegina, sometimes copying verbatim sections from the *Ḥāwī*. If this were so, then it would indicate a quite rapid dissemination of a treatise, for the *Ḥāwī* was not assembled in Persia till sometime after al-Rāzī's death about 313/925 and the *Taṣrīf* was written in Spain sometime in the middle to third quarter of the century. On the other hand, it is possible that both al-Rāzī and al-Zahrāwī copied from common sources.

Perhaps the best known name of all Islamic physicians is that of Abū ʿAlī al-Ḥusayn ibn ʿAbdallāh ibn Sīnā, latinized as Avicenna. He was born in 370/980 in a town near Bukhārā in Central Asia. After studying philosophy and medicine he travelled in the eastern Islamic lands. At one time he served as *wazīr* in Hamadān, in western Persia not far from Baghdād, to the Buwayhid ruler Shams al-Dawla Abū Ṭāhir (reg. 387–412/997–1021). Ibn Sīnā died in 428/1037, and he was known as one of the greatest philosophers of Islam and in medicine was so highly regarded that he was compared with Galen. He was a most prolific writer, for we know of nearly 270 titles of compositions. Among his smaller medical writings were a didactic poem on medicine, a poem on sexual hygiene, a treatise on cardiac drugs concerned with the physiology and pathology of the heart and how they are influenced by emotions and the simple remedies for regulating heart beat, and treatises on bloodletting, on diagnosis from respiration and pulse, on colic, on intermittent fevers, on diabetes and on hygiene and regimen.

Ibn Sīnā's magnum opus by which he is known East and West is the *Kitāb al-Qānūn fī al-ṭibb* or *Canon of Medicine*. It was composed over a lengthy period of time as he moved westward from Gurgān, in northern Persia where it was begun, to Rayy and then to Hamadān even further southwest where he completed it. This large comprehensive encyclopedia rivalled, and in many quarters surpassed, the popularity of al-Majūsī's compendium. In contrast to al-Majūsī and al-Rāzī, Ibn Sīnā cites no sources whatever. He divided his compendium into five books. The first consisted of four parts: (1) on the elements, humors, temperaments, anatomy of the homogeneous parts (bones, muscles, nerves, arteries, veins) and the three faculties; (2) the six 'non-naturals', general symptoms of diseases and diagnosis by pulse, urine and stools; (3) hygiene and regimen in health and illness for children, adults and the aged, as well as effects of climatic change and medical advice for travellers; and (4) general methods of therapy including cathartics, emetics, enemas, fomentations, liniments, bloodletting, cautery, some surgery such as amputation and the relief of pain.

The second book of the *Qānūn* is on simple drugs (*materia medica*) arranged alphabetically following a discussion of the general properties of drugs. The third book covers diseases peculiar to certain parts of the body, presented in order from head to toe, giving the anatomy of the heterogeneous or compound parts as well as causes, symptoms and treatment of each disease associated with that part. The fourth book covers diseases not specific to any one part of the body and is divided into four parts: (1) on fevers, (2) on pustules, abcesses, ulcers, swellings, leprosy, smallpox, wounds, fractures and dislocations, (3) on poisoning and animal and insect bites, and (4) on cosmetics, obesity and emaciation, and care of hair, skin, nails, offensive odors etc. The last, fifth, book is a formulary giving recipes for compound drugs which are referred to by name in the third and fourth books.

Ibn Sīnā opens the *Qānūn* with what may be a veiled criticism of al-Majūsī's two-part division of his work into the theoretical and the practical:[16]

> I say that medicine (*tibb*) is a science (*'ilm*) in which one learns the states of the human body with respect to what is healthy and what deviates from it, for the purpose of preserving health when it already exists and restoring it when it has been lost.
>
> To the person who says that medicine is divided into theory (*naẓar*) and practice (*'amal*) and that you have combined all of it under theory when you said that it was a science par excellance – to this person, we say that in the arts (*sinā'āt*) there is what is theoretical and practical and in philosophy there is what is theoretical and practical, and that in medicine there is [also] what is theoretical and what is practical. But the meaning of the expression theoretical and practical is something different in each category. It is not necessary now to explain the difference of meaning except in the case of medicine. When it is said that in medicine there is that which is theoretical and that which is practical, it does not follow that one should think the meaning to be that one of the two divisions of medicine is the learning of science (*'ilm*) and the other division the practice of it through practical work, as it is believed by many of the investigators into this subject. Rather it is right that you understand that the meaning is something different – namely, that it is not that only one of the two divisions of medicine is a science, but that one of the two is the science of the principles of medicine and the other the science of the particulars of practice. Then the first of the two is assigned the name science (*'ilm*) or theory (*naẓar*), while the other is allotted the name practice (*'amal*). So we mean by the theoretical part of it, that in which there is

> information useful for establishing a firm foundation only but not going into an explanation of the details of practice. For example, it is said in medicine that the categories of fever are three and that the temperaments are nine. We mean by the practical aspect of it, not the actual practice nor the application of bodily movements, but rather the part of the science of medicine in which the information is useful for a concept, that concept being related to the explanation of the details of practice. For example, it is said in medicine that inflammed swellings require that in the beginning there should be put on them that which is styptic and cools and thickens; then after that the styptics are mixed with emollients. After achieving a decrease in size, [treatment] is confined to emollients which resolve, except in swellings which are a result of matter which vital organs expell. So this information is useful to you as a concept which explains the particulars of practice. If you learn these two divisions, then you will achieve theoretical knowledge and practical knowledge, even if you never practice.

Ibn Sīnā in general excells in the logical assessment of a condition and the comparison of symptoms. For example, his brief statement regarding the difference between smallpox and measles is considerably more explicit than anything written by al-Rāzī, although the latter excells in therapeutics. Ibn Sīnā says:[17]

> Know then that measles is like a bilious smallpox, there being no distinction between them in most cases. The only distinction between them is that measles is bilious, and it is smaller in size, appears not to penetrate the skin, and has no thickness which is discernable, especially at its onset, while smallpox has at the first of its outbreak a protruberance and thickness. And it [measles] is less extensive than smallpox and occurs less frequently on the eyes than smallpox. But the symptoms of its outbreak are close to the symptoms of the outbreak of smallpox, but the vomiting is greater and the mental distress and inflammation are more severe while the pain in the back is less, because in smallpox there is a tendency toward it [pain] due to the repletion of blood extending along the vessels positioned along the back. Indeed smallpox is formed with a large amount of corrupt blood, while measles [occurs] due to the severity of the bad quality of [only] a little corrupt blood. And measles in most cases comes out all at one time, while smallpox [occurs] one [spot] after another.

Ibn Sīnā's approach to general therapeutics can be illustrated by his section on the relief of pain:[18]

> In short, that which relieves pain either changes the temperament, or resolves the disease matter, or is analgesic (*mukhaddir*). The analgesia (*al-takhdīr*) abates the pain because it destroys the sensation of that part, and it destroys its sensation in one of two ways: either through hypercooling or by means of the poisonous property in it which counterbalances the strength (*quwwa*) of the part . . . .

Of the analgesics (*mukhaddirāt*), the most powerful is opium, and of the same class is mandrake, its seeds and root bark, the two varieties of poppy, henbane, hemlock, the soporific black nightshade, and lettuce seeds. And also in this class are cold water and ice.

Frequently an error occurs regarding the pains, for their causes may be external matters, such as heat or cold, or an incorrect arrangement of the pillow, or a poor bed, or a fall during drunkenness, and other such things. So [in such cases] seeking a cause for it in the body results in an error. Consequently, it is necessary that you determine that and find out whether there is repletion (*imtilā'*) there or not and whether there are any causes for the given repletion. Sometimes the cause would have arisen externally but had an effect internally. For example, one who drinks cold water experiences severe pain in the region of his stomach and liver. Often there is no need for strong measures of evacuation and such, for frequently bathing and sound sleep are sufficient. Similarly, for a person who eats something hot and then gets a severe headache, it is enough that he drink cold water . . . .

. . . He [the one treating, *mu'ālij*] needs to possess a strong intuition in order to determine which of two periods of time are to be longer – the period in which the strength is maintained or the duration of the pain, and also which of two conditions are more harmful, the pain or the possible danger in the analgesia; and so he must choose the course which is best. Sometimes if the pain remains, its severity and intensity can cause death. But analgesia sometimes causes death, although it is more often harmful in other ways. Sometimes you are able to remedy its harmfulness and resume [using] it and apply it in a proper treatment. In addition, you need to consider the preparation of the analgesic and its details, so that you use it in the mildest way and use it compounded with theriacs, unless there is a very compelling reason which requires a powerful analgesia. Sometimes some of the parts are not [adversely] affected by the use of analgesics on them, for they do not involve great danger, like the teeth, when analgesics are placed on them. And sometimes oral administration is also safe, such as drinking an analgesic for pain in the eye, for that is less dangerous to the eye than using it as a collyrium on the eye. With other parts, occasionally the harm which accompanies its oral administration is easily remedied. As for colic, the danger is great because the disease matter becomes increasingly cold, congealed, and obstructed.

Analgesics may relieve pain by the property in them which causes sleep, for sleep is one of the means of alleviating pain, especially when fasting is used along with it, in a physical (*māddī*) pain. But analgesics compounded, so as to dilute their strength, with drugs such as theriac are safer . . . .

Among the pains which are severe but easily treated at times are the pains of flatulence. Sometimes it is sufficient for relieving it to pour hot water over it [the painful area], but there is a peril in this procedure. . . . Applications of hot compresses (*takmīd*) are also one of the treatments for flatulence, but it is better to use something dry like millet . . . . Water in a [animal] bladder can also be applied as a compress, being safe and mild, but the result already mentioned [producing burns] might take place if care is not taken. Cupping

> with heat is of this same sort of procedure, and it is effective for relieving the pain of flatulence. ...
>
> Among the means of lessening pain is gentle, long walking, because of the relaxation in it. Similarly, [the massaging of] the well-known light fats and the oils already mentioned, as well as sweet music, especially when accompanied by sleep, and being occupied with something very enjoyable – [all] are means of alleviating pain.

Ibn Sīnā's concern is not only with the administration of analgesic drugs but also with other means of relieving pain, such as massage, use of a hot-water bottle, pleasurable music, or compelling work. What is equally interesting is what is not stated: there is no mention of the use of wine, though wine is used for other purposes elsewhere in the *Qānūn*, nor is there any mention of the use of analgesics or soporifics during an operation.

These comprehensive attempts at collecting and systematizing, as well as updating with personal observation, the fragmentary and unorganized Hellenistic, Byzantine and Syriac medical literature which was their heritage, were enormously successful in producing a coherent and orderly medical system. This system, essentially Galenic in nature but much modified and elaborated, was so brilliantly clarified by these compendia (especially those by al-Majūsī and Ibn Sīnā), and such order and consistency brought to it, that a sense of perfection and hence stultifying authority resulted. The sheer size of these compendia tended to emphasize their authoritative nature. In the case of Ibn Sīnā even the title *Qānūn* (canon or law) contributed to this view. Furthermore, as the medical historian Michael McVaugh has aptly noted:[19] 'Such treatises ... however much they might emphasize the importance of practical knowledge, or the nature of medicine as "art", the effect of their very structure was to favor the logical element over the clinical.'

The *Qānūn* of Ibn Sīnā was not, however, greeted everywhere with praise. In Spain the physician Ibn Zuhr (d. 525/1131), father of the eminent Ibn Zuhr known in Latin as Avenzoar, wrote a treatise criticizing parts of Ibn Sīnā's book on *materia medica*, i.e. the second book of the *Qānūn*. We have the following account of Ibn Zuhr's reaction to first reading the *Qānūn*:[20]

> You recounted what you had been told regarding the learned and excellent medical practitioner (*mutaṭabbib*) of Andalusia [Ibn Zuhr] – which is to say, that a merchant had brought from Iraq a copy of this book [the *Qānūn*], a copy which had attained a high level of perfection. So he presented it to him [Ibn Zuhr] to curry favor. He [Ibn Zuhr] had not encountered this book before, but when he examined it, he found fault with it and rejected it and did not put it into his library. [Rather] he set about cutting off its margins, on which he would then write a copy of prescriptions for the patients who

> would consult him. And you recounted that it was said that the book was not suitable for those beginning the study of medicine because of the unusual terms and philosophic meanings which it contains.

This account is particularly interesting on two counts. First, it shows that it was about a century before the *Qānūn* became available in Córdoba after it was completed in Hamadān. Secondly, since this Ibn Zuhr was the first of a five generation family of prominent Andalusian physicians, the question arises whether Islamic medicine in Spain followed the direction of this patriarch of medical families and developed with less dependence upon the ideas of Ibn Sīnā.

Our source of information on Ibn Zuhr's opinion of Ibn Sīnā is Hibat Allāh ibn Jumayʿ al-Isrā'īlī who was physician to al-Malik al-Nāṣir Ṣalāḥ al-Dīn, known as Saladin (reg. 564–89/1169–93). Hibat Allāh replied to Ibn Zuhr's criticism with the following, not wholly uncritical, rebuttal:[21]

> I say that the condemnation and censure which Ibn Zuhr heaped on the master's book was [merely] straightforward prejudice. Now this book [the *Qānūn*], even though its compiler had put into it some artificial expressions and things which are remote and not connected with the sciences and there is in it a certain amount of ambiguity, omission, grammatical error, contradiction, confusion, and inadvertent mistakes, as we have said, and these occur in many passages, it is nonetheless a book which encompasses the principles and rules of medicine in a way that other large compendia do not. And then there is in it authority, brevity, good writing style, organization, and clarity of explanation, which are lacking in other books. Consequently, its great faultiness is offset by these qualities it possesses, and the endurance of inaccuracy and imperfection is easily tolerated because of them. In short, among all the large compendia we have today, there are none which could take its place or fill its position.

It appears that, having achieved a high level of exhaustive systematization, an awareness set in that these compendia were too large to be really useful for ready reference. As a reaction to compendia such as the *Qānūn*, simplification, elucidation, and fragmentation dominated the Islamic medical writings after the middle of the fifth/eleventh century. Thus, epitomes of the *Qānūn* were produced to make the ideas more quickly accessible; commentaries were made to clarify the contents; and the number of treatises on single topics were increased. Few writers undertook to produce a compendium on the scale of Ibn Sīnā or al-Majūsī.

In contrast to those learned medical men concerned with synthesizing vast quantities of knowledge, brief mention might be made here of two physicians of the fifth/eleventh century. ʿAlī ibn Riḍwān (d. 460/1068) resided in Old Cairo (Fusṭāṭ) and was appointed Chief Physician of Egypt (*ra'īs aṭibbā' Miṣr*) by the Fāṭimid caliph al-Mustanṣir (reg. 427–87/1035–94).

His treatise *On the Prevention of Bodily Ills in Egypt* (*Kitāb Dafʿ maḍārr al-abdān bi-arḍ Miṣr*) was written to refute the opinions of a fourth/tenth-century Tunisian physician, Ibn al-Jazzār, and it is a fascinating discourse on the climatological problems in Egypt and their relation to public sanitation and diseases, particularly plague, among Egyptians. While a contemporary of Ibn Sīnā, Ibn Riḍwān does not seem to have been familiar with Ibn Sīnā's compositions.[22] In addition to some commentaries on various Galenic treatises and an essay on the training of physicians, he is well known for a debate he had with a physician of Baghdād. This was Ibn Buṭlān, a leading Christian physician who about 441/1049 visited Old Cairo, where he got to know Ibn Riḍwān. While he was in Cairo, an acrimonious disagreement occurred between the two of them, and they each prepared an exchange of opinions on various philosophical and medical problems, including the influence of climate, seasons and race on health and whether remedies prescribed in Baghdād were appropriate in Cairo.

After leaving Cairo, Ibn Buṭlān did not return to Baghdād, but went to Constantinople and then settled in Antioch and became a monk. He composed a satirical piece exposing quackery called *The Dinner Party of Physicians* (*Daʿwat al-aṭibbāʾ*), which presents a round-table discussion of an oculist, surgeon, phlebotomist, druggist and a physician, in addition to Ibn Buṭlān himself. He also wrote a medical manual for the use of monks, a tract on how to detect illnesses in slaves that were for sale, and a popular *Almanac of Health* (*Taqwīm al-ṣiḥḥa*) presenting hygiene and dietetics in a tabular format.

## PROPHETIC MEDICINE

By the fourth/tenth century there arose a genre of medical writing which developed parallel to that based upon the Hellenistic and Byzantine system of medicine. Most treatises of this type were titled *al-ṭibb al-nabawī*, 'prophetic medicine', and in the seventh/thirteenth and eighth/fourteenth centuries the topic attracted particular attention. The purpose of this type of medical writing appears to have been twofold: to attest to the religious value of medicine by asserting that medicine represents the highest service to God, and to appropriate medicine for Islam rather than allow it to be dominated by foreign (i.e. Greek-based) traditions. Prophetic medicine assumed the religious and philosophical position that certainty of knowledge could only be obtained from revelation, the Prophet Muḥammad, and the customs and opinions of his immediate followers. Thus, the final authority for medicine is prophetic revelation and not Galen or Hippocrates or Ibn Sīnā.

The earliest treatise on prophetic medicine seems to be that written by Ibn al-Sunnī (d. 364/974).[23] From extant texts it appears that all the authors were religious scholars. While most were Sunnī Muslims, sometimes called orthodox, there were also Shīʿī writers. For example, at the end of the fourth/tenth century two brothers, Abū ʿItāb ʿAbdallāh and al-Ḥusayn ibn Bisṭām ibn Sābūr, compiled a tract on the subject, using Shīʿī Imāms as authorities.

For all writers on prophetic medicine, prevention was always better than cure. The Sunnī writers never actually opposed the use of medicines, but the Shīʿī versions tend to allow the taking of medicine only if there were no other alternative and the complaint was unbearable. The Shīʿī tracts were perhaps the most extreme and fatalistic, with therapy in some treatises consisting mostly of prayer and the assurance that patient endurance of illness will be rewarded by God.

Some prophetic medical treatises were written as straightforward, but alternative, medical texts – texts which incorporated and attempted to reconcile the native medicine of Arabia and the revelations of Muḥammad with ideas and terminology from the Greek-based system. Examples are the treatise by al-Dhahabī (d. 784/1348), who frequently cites Ibn Sīnā and Hippocrates in addition to religious authorities, and that by al-Azraq written at the beginning of the ninth/fifteenth century. The latter author quoted in full the religious authorities, while describing and giving therapies for a large number of diseases found in the Greek-based medical compendia and allotting space to discuss protection against the evil eye. Such treatises were written not as much to oppose the Greek-based system as to assimilate it into the traditional Islamic culture.

On the other hand, the writings of Ibn al-Jawzī (d. 597/1200) and the popular treatise by al-Suyūṭī (d. 911/1505), who also wrote an Islamic cosmology on the same principles, are based almost exclusively upon what was known of the practices current in the days of Muḥammad, derived from the *Qur'ān*, the reports about Muḥammad (*ḥadīths*) and the practices of the early Muslim community (*sunna*). Various therapies were given, consisting of diet and simple drugs (especially honey), bloodletting and cautery (which according to some was forbidden), with no surgery. Other topics included fevers, rabies, smallpox, leprosy, plague, poisonous bites, protection from night-flying insects, protection against the evil eye, rules of coitus, theories of embryology and anatomy, general conduct of physicians and treatment of minor illnesses such as headaches, nosebleed, cough, colic and sciatica. It was prohibited to drink wine or use soporific drugs as medicaments.

The medical practices advocated in such writings reflect popular beliefs in sympathetic magic and the native customs of the early Islamic community. From a medical standpoint, there is no comprehensive or consistent underlying theory in the prophetic medical texts, for they are based on fragmentary knowledge of pre-Islamic and early Islamic practices, which in any case were unlikely to have ever been encompassed by a consistent medical theory or system. From a philosophical viewpoint, however, prophetic medicine presents a medical system based upon religious or supernatural authority.

We know of a considerable number of prophetic medicine treatises, all written by religious authorities. We do not, however, have the names of any medical practitioners who were known for practicing this type of medicine. The reason for this, of course, may well be that our written sources are for the most part skewed toward the Greek-based system and omit details of other practices.

Treatises on prophetic medicine flourished for centuries alongside those of the Greek-based tradition, but probably serving a different part of the community. It is certainly too harsh an assessment to describe the tracts on prophetic medicine as 'quackery piously disguised'.[24] Quackery implies a conscious effort to defraud. Prophetic medicine was certainly believed in by its proponents. It arose through an attempt to preserve medical knowledge at a stage known to the Prophet Muḥammad (since, it was argued, that allowed greater certainty of truth) and to prevent the intrusion of foreign elements to the point where they dominate. The growth of this genre of medical literature was not a direct threat to 'scientific' or 'rational' medicine, nor did it alone bring about the decline of science and medicine, but rather it was symptomatic of a frame of mind with which an increasing proportion of the society was being absorbed.

It is noteworthy that those physicians trained in the Greek-based tradition (no matter what their own particular religious beliefs) did not criticize the prophetic medicine tradition, even when voicing great concern for inept and fraudulent medical practitioners. The only criticism – and that is a very mild one – to be noted so far is in the world history written by Ibn Khaldūn in the eighth/fourteenth century, who speaking of prophetic medicine says:[25]

> He [Muḥammad] was sent to teach us the religious law. He was not sent to teach us medicine or any other ordinary matter. In connection with the fecundation of the palms and what resulted, he said : 'You know more about your worldly affairs [than I]'.
>
> None of the statements concerning medicine that occur in the reliable *ḥadīth* should be considered [to have the force of] law. There is nothing to indicate that this is the case. The only thing is that if that type of medicine is used for the sake of a divine blessing and in true religious faith, it may be very useful. However, that would have nothing to do with humoral (*al-mizājī*) medicine but be the result of true faith.

A comparison between these treatises on prophetic medicine and Islamic plague tracts might prove instructive. Both types of writings were especially popular in the seventh/thirteenth and eighth/fourteenth centuries and later. The plague tracts have as their primary focus the collecting and interpreting of various *ḥadīths* which were considered relevant to the ideas of infection and the proper reaction to such occurrences, although they also attempted some medical explanations and remedies for the plague and sometimes a history of plagues up to the time of composition. They, like the treatises on prophetic medicine, were written for the most part by religious scholars, although a few were composed by writers trained both as physicians and theologians.

## AYYŪBID AND MAMLŪK PATRONAGE

Egypt and Syria were ruled by two successive dynasties noted for their patronage of hospitals and physicians. The Ayyūbid line of Kurdish descent was founded in Egypt by Saladin in 564/1164, who overthrew the Shīʿī Muslim Fāṭimid rule and established orthodox Sunnī Muslim religious policies. He also undertook the *jihād* against the Crusaders, thereby regaining lands conquered by the Christians. Nūr al-Dīn Maḥmūd ibn Zangī, a Turkish prince of the *atābeg* line, was at that time ruler of Syria, and when Saladin first established himself in Egypt he was in the service of Nūr al-Dīn. Not long after his suzerain Nūr al-Dīn died in 569/1174, Saladin made himself ruler of both Egypt and Syria.

Nūr al-Dīn had founded in Damascus a hospital which was named after him the Nūrī hospital. Saladin followed his example and founded in 567/1171 a hospital in Cairo called the Nāṣirī hospital, named after himself, his full name being al-Malik al-Nāṣir Ṣalāḥ al-Dīn Yūsuf ibn Ayyūb. Both of these hospitals operated for many years and attained great fame.

The Mamlūks arose in 648/1250 from the professional Turkish slave guards and soldiery in the service of the last Ayyūbid ruler, and they ruled as an independent dynasty in Egypt and Syria for two and a half centuries. Under the patronage of the Mamlūks not just medicine but astronomy, architecture, metalwork, book production and binding, glassware and ceramics prospered. Improvements were carried out in both Damascus and Cairo on hospitals, public and religious buildings, canals, bridges and the postal service, resulting in the communication between the two cities being reduced to a week or less. In Cairo the Mamlūk ruler al-Malik al-Manṣūr Sayf al-Dīn Qalā'ūn completed in 683/1284 a complex containing a mosque, tomb, school and hospital. This hospital was named the Manṣūrī in his honour.

Under both the Ayyūbids and the Mamlūks Egypt and Syria were ruled as one area, with frequent and regular contacts between the two major cities of Cairo and Damascus and consequently between their medical communities. Saladin was said to have had not less than eighteen physicians in his service, eight of them Muslims, five Jews, four Christians and one Samaritan. These included the well-known Jewish physician and philosopher Mūsā ibn Maymūn (Maimonides) and Hibat Allāh ibn Jumayʿ al-Isrāʾīlī. The former, Maimonides, was born and educated at Córdoba and is most famous for his *Aphorisms* (*Kitāb al-Fuṣūl*), though he also wrote on asthma, on regimen, on the symptoms of diseases and on various other topics. Ibn Jumayʿ al-Isrāʾ īlī had been a student of a Fāṭimid court physician named Ibn al-ʿAynzarbī and in turn had students of his own, including Ibn Abī al-Bayān al-Isrāʾīlī (d. 638/1240), the author of a *Hospital Formulary* (*Dustūr al-bīmāristānī*) for use in the Nāṣirī hospital.

Following the death in 560/1165 of the head physician of the ʿAḍudī hospital in Baghdād, Ibn al-Tilmīdh, at the age of 95, several physicians who had been students of his left Baghdād for Damascus and the Nūrī hospital, which by then had been in operation about 10 years. One of those to leave for Damascus was Raḍī al-Dīn al-Raḥbī who lived, like his teacher Ibn al-Tilmīdh, to a very old age, for he died in Damascus in 631/1233 at the age of 97. During his long life he instructed many in the art of medicine. Another of Ibn al-Tilmīdh's students to emigrate was Ibn al-Muṭrān (d. 587/1191), a Christian who converted to Islam and found in Saladin a generous patron, enabling him to develop a personal library said to contain 10,000 volumes at his death.

Muhadhdhab al-Dīn ʿAbd al-Raḥīm ibn ʿAlī, known as al-Dakhwār, was the leading influence on the development of learned medical care in Syria and Egypt in the seventh/thirteenth century. He was born and raised in Damascus where his father and brother were oculists, and he died there in 628/1230. Al-Dakhwār studied medicine with both Ibn al-Muṭrān and Raḍī al-Dīn al-Raḥbī, and he became personal physician to the Ayyūbid ruler al-Malik al-ʿĀdil Sayf al-Dīn, the brother of Saladin. He accompanied al-Malik al-ʿĀdil to Egypt and at the time of an epidemic in 612/1216 successfully treated the Ayyūbid ruler's son, after which he was appointed 'Chief of the Physicians in all of Egypt and Syria'. He returned to Damascus where he was associated with the Nūrī hospital and taught many students.

The two most famous pupils of al-Dakhwār were Ibn Abī Uṣaybiʿa and Ibn al-Nafīs. Ibn Abī Uṣaybiʿa, who died in 668/1270 was born into a family of physicians in Damascus and in his day was a noted oculist practicing at the Nūrī hospital, though today we more readily associate his name with his book *Sources of Information on the Classes of Physicians* (*Kitāb ʿUyūn al-anbāʾ fī ṭabaqāt al-aṭibbāʾ*) in which he gives the biographies of over 380 physicians. Curiously, however, his fellow student Ibn al-Nafīs is not mentioned in his bio-bibliographical history, even though he devotes two chapters to his contemporaries in Syria and Egypt.[26] We can only guess that there was a great rivalry, and perhaps even personal enmity, between the two physicians.

Ibn al-Nafīs, better known in the Arabic literature by his *nisba* al-Qurashī, was an authority on religious law, logic and theology, as well as a prolific writer of medical tracts. He undertook an enormous compendium of medical knowledge which was projected to be 300 volumes, of which he completed only 80; of these we unfortunately have today only three. Among his other writings were a summary of ophthalmological practices, a commentary on the *Questions on Medicine for Students* by Ḥunayn ibn Isḥāq and a very popular epitome (*Mūjiz*) of the *Qānūn* of Ibn Sīnā.

Ibn al-Nafīs also composed a commentary on the entire *Qānūn* (*Sharḥ al-Qānūn*) which became an authoritative work in its own right. In this commentary he criticized Ibn Sīnā for separating his discussion of anatomy into two parts (the anatomy of the homogeneous parts in the first book and the anatomy of the compound parts in the third book) and for failing to have the book on compound drugs immediately following that on simple drugs. Consequently Ibn al-Nafīs prepared a separate commentary on the anatomy of the *Qānūn* (*Sharḥ tashrīḥ al-Qānūn*), treating the two sections together, which he intended to have follow the commentary on the first book of the *Qānūn*. It is in this anatomical commentary that Ibn al-Nafīs set forth his insight into the nature of the pulmonary circulation for which he is today reknown. Nearly all copies of his commentary on the complete *Qānūn* lack the commentary on the anatomy, and even in the eighth/fourteenth century physicians complained that the larger commentary very rarely contained the anatomical commentary. The physician Zayn al-ʿArab al-Miṣrī writing in the eighth/fourteenth century tells of another physician who, after repeated attempts to acquire a copy, was informed that Ibn al-Nafīs had delayed the writing of the anatomical commentary until the very end of his life, for which reason it was not included in the copies of the complete commentary.[27] While Ibn al-Nafīs may have composed his commentary on the anatomy after completing the general one on the *Qānūn*, it is certain that he wrote the commentary on the anatomy rather early in his career, for there is extant today a manuscript copy of this commentary made some 46 years before Ibn al-Nafīs's death.[28] Ibn al-Nafīs spent much of his life in Cairo, where he became Chief Physician, and died there in 687/1288, bequeathing his house and library to the recently constructed Manṣūrī hospital in Cairo.

In Damascus an important pupil of both Ibn al-Nafīs and Ibn Abī Uṣaybiʿa was the Christian physician Ibn al-Quff, who died there in

685/1286. He taught medicine himself in Damascus and was one of the very few physicians to compose a treatise devoted only to surgery. This manual (*Kitāb al-ʿUmda fī ṣināʿat al-jirāḥa*) covered all aspects of surgical care except ophthalmological procedures. He considered the treatment of eye diseases to be a clear-cut speciality with its own technical literature.

Indeed monographs on ophthalmology were produced by several Syro-Egyptian physicians, in addition to that by Ibn al-Nafīs. Among these was an ophthalmological manual by Muḥammad ibn Ibrāhīm al-Akfānī (d. 749/1348) of Cairo, who prepared an abridged form of his manual as well. In the following century the Egyptian oculist Nūr al-Dīn ʿAlī ibn Muḥammad al-Munāwī al-Shāfiʿī wrote on the same topic. The treatise by al-Munāwī, however, actually consists of the abridgement which al-Akfānī wrote of his own treatise, alongside of which al-Munāwī placed the text of al-Akfānī's longer manual as well as all the relevant passages from the *Perfected Book on Ophthalmology* by Ibn al-Nafīs. This work of al-Munāwī is representative of the decline in originality characteristic of the majority of medical compositions after the eighth/fourteenth century.

## HOSPITALS

The hospital was one of the great achievements of medieval Islamic society. The relation of the design and development of these hospitals to the earlier and to the contemporaneous Byzantine hospitals, as well as their consequent influence upon later European ones, has yet to be clearly delineated. There is much current research being undertaken on this topic.

In Islam there was generally a moral imperative to treat all the ill regardless of their financial status. The hospitals were largely secular institutions open to all, male and female, civilian and military, adult and child, rich and poor, Muslims and non-Muslims. They tended to be large, urban structures.

The Islamic hospital served several purposes: a centre of medical treatment, a convalescent home for those recovering from illness or accidents, an insane asylum and a retirement home giving basic maintenance needs for the aged and infirm who lacked a family to care for them. In the first two instances, admission would be for a limited period of time, with the view of curing a particular disorder. In the last category, it is unclear how many, if any, were of the truly indigent and uneducated classes. The records we have from Cairo of individuals who spent their final years in a Mamlūk hospital indicate that they were *ʿulamāʾ* (religious scholars) lacking children and sufficient financial resources. It is most unlikely that any truly wealthy person would have gone to a hospital for any purpose, unless they were taken ill while travelling far from home. Except under very unusual circumstances all the medical needs of the wealthy and powerful would have been administered in the home or through outpatient clinics dispensing drugs. Though Jewish and Christian doctors working in hospitals were not uncommon, we do not know what proportion of the patients would have been non-Muslim. There are no notices of Jewish patients, except in fourth/tenth-century Baghdād, probably because of the differing dietary laws. The care for the insane in hospitals was unprecedented and an important part of even the earliest Islamic hospitals.

An Islamic hospital was called a *bīmāristān*, often contracted to *māristān*, from the Persian *bīmār* (ill person) and *stān* (place). Some accounts associate the name of the early Umayyad caliph al-Walīd I (reg. 86–96/705–15) with the founding of a hospice, possibly a leprosarium, in Damascus. Other versions, however, suggest that he only arranged for guides to be supplied to the blind, servants to the crippled and monetary assistance to the lepers.

The earliest documented hospital established by an Islamic ruler was built in Baghdād probably by Yaḥyā ibn Khālid ibn Barmak, the *wazīr* to the caliph Hārūn al-Rashīd, who ruled from 170/786 to 193/809. Few details are known of this foundation, but recent research has demonstrated that Gundīshāpūr did not serve as the model. There is no evidence to associate the construction of the earliest hospital with any of the Nestorian physicians, but the prominence of the Bakhtīshūʿ family as court physicians would suggest that they also played an important role in the functioning of the first hospital in Baghdād.

In little more than a hundred years, five additional *bīmāristāns* had been built in Baghdād. According to some accounts, directions were given by a *wazīr* in the early fourth/tenth century to provide medical care to prisons on a daily basis and visits by doctors with a travelling dispensary to villages in lower Iraq. The most important of the Baghdād hospitals was that established in 372/982 by the Buwayhid ruler ʿAḍud al-Dawla. When it was founded it had twenty-five doctors, including oculists, surgeons and bonesetters. In 580/1184 a traveller described it as being like an enormous palace in size.

In Egypt, the first hospital was built in al-Qaṭāʾī, in the southwestern quarter of present-day Cairo, in 260/872 by Aḥmad ibn Ṭūlūn, the ʿAbbāsid governor of Egypt. It is the earliest for which there is clear evidence that care for the insane was provided. Before AD 900, two hospitals were also said to have been built in Fusṭāṭ (Old Cairo), though the evidence on this point is questionable. In the twelfth century, Saladin founded the Nāṣirī hospital in (new) Cairo, but it was surpassed in size and importance by the Manṣūrī, completed in 683/1284 after eleven months of construction. The Manṣūrī hospital remained the primary medical centre in Cairo through the ninth/fifteenth century. The Nūrī hospital in Damascus was a major one from the time of its foundation in the middle of the sixth/twelfth century well into the ninth/fifteenth century, by which time the city contained five additional ones.

Besides those in Baghdād, Damascus, and Cairo, hospitals were built throughout Islamic lands. In al-Qayrawān, the Arab capital of Tunisia, a hospital was built in the third/ninth century, and early ones were established at Mecca and Medina. Persia had several, and the one at Rayy was headed by al-Rāzī prior to his moving to Baghdād. Ottoman hospitals flourished in Turkey from the seventh/thirteenth century, and there were hospitals in the Indian provinces. Hospitals were comparatively late in being established in Islamic Spain, the earliest possibly being built in 768/1397 in Granada.

Of the great Syro-Egyptian hospitals of the sixth/twelfth and seventh/thirteenth centuries, we possess a considerable amount of information on their organization. They were built on a cruciform plan with four central *īwāns* or vaulted halls, with many adjacent rooms including kitchens, storage areas, a pharmacy, some living quarters for the staff and sometimes a library. Each *īwān* was usually provided with fountains to provide a supply of clean water and baths. There was a separate hall for women patients and special areas reserved for the treatment of conditions particularly prevalent in the area – gastrointestinal complaints (especially dysentery and diarrhoea), eye ailments and fevers. There was also an area for surgical cases and a special ward for the mentally ill. Some had an area for rheumatics and cold sufferers (*mabrūdūn*). There frequently were outpatient clinics with a free dispensary of medicaments. The staff included pharmacists and a roster of physicians who were required at appointed times to be in attendance and make the rounds of patients, prescribing medications. These were assisted by stewards and orderlies (*mabāshirūn* and *mushārifūn*), as well as a considerable number of male and female attendants (*farrāshūn*) who tended the basic needs of the patients. There were also instructors (*muʿallimūn*), possibly aspiring medical students, who trained the non-professional staff. The budget of such institutions must have been considerable, and in fact the budget of the Manṣūrī hospital in Cairo was the largest of any public institution there. Over the entire staff and responsible for the management of the hospital was an administrator (*nāẓir*) who was not usually trained in medicine. In most instances he was a political appointment, subject to the unpredictable fluctuations of political favour, for the position of controller of a hospital was a very lucrative one. The chief of staff, on the other hand, was a medical man.

All the hospitals in Islamic lands were financed from the revenues of charitable trusts called *waqfs*. Wealthy men, and especially rulers, donated property as endowments, whose revenue went toward building and maintaining the institution. The property could consist of shops, mills, caravanserais or even entire villages. The income from an endowment would pay for the maintenance and running costs of the hospital, and sometimes would supply a small stipend to the patient upon dismissal. Part of the state budget also went toward the maintenance of a hospital; the services of the hospital were to be free, though individual physicians might charge fees.

Little detailed information is available regarding the hospitals as teaching institutions. We have accounts of teaching at certain hospitals, such as the ʿAḍudī hospital in Baghdād, but how many hospitals had such formal classes is not known. Clinical training at the bedside in a hospital, whether as an apprentice or through formal instruction, was, however, a part of medical learning for a substantial number of formally trained physicians. Whether such students received a stipend, as they did in other teaching institutions such as a *madrasa* (a school of Islamic law), is unclear. The encouragement of students to acquire clinical training is illustrated in the following quotation from al-Majūsī, who served as physician to the founder of the ʿAḍudī hospital in Baghdād.[29]

> One of the requirements for the student of this art is that he should be in attendance at the hospitals and the places of the sick, [having] extensive consultation with the most skilled teachers among the physicians regarding their [the patients's] situations and circumstances, and frequent examination of the conditions of the patients and the symptoms apparent in them, calling to mind what he has read about these conditions and what they indicate of good and evil. If he does this, he will reach a high degree of perfection in this art.

## THE ART AS A PROFESSION

Information regarding the number of medical practitioners in medieval Islamic cities is meagre and difficult to interpret. It has been estimated that in Baghdād in 319/931 there was a ratio of about one physician per 300 inhabitants.[30] Doubtless there were areas, particularly rural areas, where there were no formally trained physicians at all, for there were many self-help guides to basic medical care intended for use in travelling and when no physician was available.

At the top of the profession in terms of prestige and income were those enjoying the patronage of a caliph, ruler or *wazīr*. Such positions were not without risk, however, for the patron could be at times ruthless or whimsical. Rulers were known even to confiscate libraries or imprison their physician, and more than one physician has been known to lose favour rapidly through failing to cure a powerful patron. Some of the most learned physicians also excelled in other fields, such as theology and philosophy, and won acclaim and income by teaching or writing in these areas as well. It seems that association with a hospital was a mark of prominence, and only the more respected had such positions.[31] Aside from those who enjoyed the favour of a wealthy person, it is likely that the majority of doctors had incomes similar to those of shop-keepers or merchants.[32]

Among the writings of nearly all the learned physicians are frequent anecdotes about inept physicians, quacks and charlatans. Much of this appears to reflect the common human tendency, evident in literature from classical antiquity to the modern day, of decrying the decline of standards. On the other hand, it also reflects the lack of any clearly established regulation by the state or self-regulation by the profession.

The extent to which the practice of charlatans was a serious problem is difficult to gauge. The most important source on the methods used by such charlatans is the seventh/thirteenth-century Syrian writer ʿAbd al-Raḥīm ibn ʿUmar al-Jawbarī, who was himself a professional slight-of-hand artist who spent most of his life in Damascus. He wrote an entire book on exposing fraudulent practices, and several chapters are devoted to itinerant physicians and drug sellers.

An early critique of medical charlatans is that given by al-Rāzī in his medical book dedicated to Manṣūr.[33]

> The tricks of these people are numerous and it would be difficult to mention all of them in a treatise such as this. They are insolent and believe they can inflict pain on the public for absolutely no reason at all. There are among them those who claim that they can cure epilepsy by making a cross-shaped incision on the middle of the head. Then they produce things they have brought with them which the patient is led to believe were extracted from the incision. Some of them pretend to extract from the nose a venomous snake. They put a toothpick or piece of iron in the nose of the unfortunate patient and rub it until blood begins to flow. Then the quack picks up from there something he had already prepared, like this animal, which he claims to have extracted from the liver. Some pretend to remove cataracts from the eyes. They scrape the eye with a piece of iron. Then they place a fine coating on it which they extract as if it were the cataract. Some pretend to suck water out of the ear. They put a tube in it and then put something into the tube from the mouth which they suck out. Some insert worms generated in cheese into the ear or into the roots of the teeth and then extract them. Some pretend to cure a person of ranula [a tumor beneath the tongue] by making an incision under the tongue and inserting a gland which they then take out as if it were the cyst.
>
> As for their insertion of bones into wounds and leaving them there for days, how often they do this! Sometimes they remove stones from the bladder and replace them with others which they proceed to extract. Frequently, they do not even check to see if there *are* stones in the bladder. Instead, they have the audacity to cut it open recklessly and insert a finger in the incision. If they find a stone, they take it out, but if not, they place one there to take out. As for

> cutting the flesh of the buttocks whenever there is a case of haemorrhoids, it is something they always do. In this way, in fact, they make people ill by causing ulcers and fistulae. Some claim to remove a certain substance (*khām*) from the penis or other part of the body, which they then tear to shreds, or they place in the glans penis, or in any other place, a tube from which they suck something that they have already put there from their mouth and pour it into a basin. Some claim they can collect a disease in one place in the body from which they can remove it. Then they rub that place with crowfoot making it itch very strongly. At that point, they ask for a fee to extract the disease from that place. If they get it, they apply an ointment and the itching stops. Some will allege that a person has swallowed fur and glass. So they use a feather to make him vomit while at the same time using the feather to put these things in the person's throat. They do all kinds of things like this and inflict great injury, even death on people. They are often undetected by knowledgeable men, for they act naturally toward the latter and so attract no attention. One does not consider them to be harmful and does not bring charges against them. However, if one were to investigate them carefully, they would be charged and their lies and falsehood would be revealed. One should not take any medicine that they give, for it has killed many.

It is noteworthy that in all these criticisms of poor or fraudulent medical practices there is no criticism of the use of amulets, talismans or incantations nor the approach advocated in prophetic medicine.

Descriptions and criticisms of the inept and the fraudulent were frequently part of larger treatises dealing with the general topic of medical ethics. In Arabic literature such deontological treatises, which also outlined the behaviour and training of good physicians, were part of a wider genre known as *adab* devoted to proper social conduct. They show much influence from Hippocratic and Galenic writings about proper medical conduct, for these latter treatises expressed many values consonant with Islamic attitudes.

The earliest Arabic deontological treatise was that by the third/ninth-century writer Isḥāq ibn ʿAlī al-Ruhāwī entitled *Adab al-ṭabīb* (*Conduct of the Physician*). Many principles were expounded. For example, the physician should be personally clean, appropriately dressed, dignified, truthful and well-read; he should earn enough to be able to raise and educate a family without needing outside income and should charge the wealthy so that he can assist the poor; and he should observe a proper code of behaviour when visiting patients. In addition, the *Aphorisms* of Hippocrates spawned in Islamic literature a succession of aphoristic writings and commentaries concerned in large part with deontological questions, the nature of the art and the proper function of the physician.

Having a literature which elaborated codes of conduct, the question then arises whether there was any way of enforcing such standards. There was certainly no uniformity in the education and training of a physician. There were families of physicians in which the training was primarily within the family. The Bakhtīshū' family is the most obvious, but there were many others as well, such as the Ibn Zuhr family consisting of five generations of Spanish physicians, including two women physicians who served the household of the Almohad ruler Abū Yūsuf Ya'qūb al-Manṣūr (reg. 580–95/1184–99). There were self-taught physicians such as Ibn Sīnā, who claimed to be self-taught in medicine though he studied other subjects with masters, and the Egyptian Ibn Riḍwān. The latter wrote a tract defending this method of training, while others, such as Ibn Buṭlān, were critical of it.

Most medical instruction was probably acquired through private tutoring and supervision. As stated earlier, there seems to have been teaching in some hospitals, especially in Baghdād and later in Damascus and Cairo. There was instruction to students other than relatives in gatherings held outside a hospital, mostly in homes or mosques. There were also some *madrasas* – i.e. schools devoted to Islamic law – which offered instruction to a few of its students in medicine and other ancillary subjects such as mathematics. However, Islamic law (*fiqh*) was always the primary focus of these institutions, with one possible exception. There is evidence that the great medical teacher of Damascus, al-Dakhwār, established upon his death a *madrasa* which had the significant feature of being devoted solely to instruction in medicine rather than Islamic law and yet like other *madrasas* provided stipends to students. His pupil, Ibn Abī Uṣaybi'a, recorded that:[34]

> When it was the year 622/1225 . . . he [al-Dakhwār] bequeathed as a charitable trust (*waqf*) his house which was in Damascus in the old goldsmiths' area east of the date-sellers market. He established it as a *madrasa* in which, after he was gone, the art of medicine would be taught. He bequeathed to it, as an endowment, estates and a number of properties, the proceeds of which would serve for its maintenance and for the salary of the teacher and the salary of those benefiting by it [the students].

According to Ibn Abī Uṣaybi'a, the *madrasa* opened, with considerable ceremony, on 8 Rabī' I, 628/15 January 1231, about a month after al-Dakhwār died. We learn from other sources that it was still in existence in 820/1417, when it underwent some repairs.

Much later sources[35] state that there were two additional *madrasas* in Damascus in the seventh/thirteenth century also devoted to medicine, but it seems likely that they were of the classic type devoted primarily to Islamic law and only secondarily concerned with medicine. The curriculum and training in such an informal system of education was not at all uniform, standardized or controlled.

In certain regions the functioning of the medical profession was overseen by a *ra'īs al-aṭibbā'* (Chief of Physicians) and a *muḥtasib*, but unfortunately we know very little about the duties of the Chief of Physicians.[36] In one instance, when Ibn al-Tilmīdh became Chief of Physicians in Baghdād, he examined the qualifications of a doctor; what this entailed we do not know. When al-Dakhwār was given 'the supervision of the physicians in all of Egypt and Syria', he was charged by the Ayyūbid ruler with[37]

> the examination (*naẓar*) in the matter of the oculists and their approach; and whoever among the oculists produced benefit through the treatment of eye diseases and satisfied him, he [al-Dakhwār] wrote for him a statement (*khaṭṭ*) by which he acknowledged it, and so he discharged his duty.

Specific details are lacking. For example, we are told neither the number of oculists involved, or the nature of the examination, nor why oculists were singled out for testing.

It was one of the duties of the *muḥtasib* – i.e. the overseer and inspector of the market places and public buildings and services – to guard against fraudulent practices not only among craftsmen but among pharmacists, surgeons and physicians. Some of his responsibilities might include seeing that correct weights and measures were employed, insisting upon proper street cleaning, seeing that a ramshackle building was condemned, ensuring a supply of clean water and other related matters, but the functions differed to some extent in various localities. A number of manuals were written as guides for a *muḥtasib* in the performance of his duties. Prior to the sixth/twelfth century they only briefly mentioned the medical profession, and then mostly in relation to matters of drugs, weights and measures. During the reign of Saladin, however, a physician working in Aleppo by the name of al-Shayzarī wrote a manual outlining the duties of the *muḥtasib* in which he discussed in considerable detail the supervising of the medical community. Perhaps the fact that al-Shayzarī was himself a physician rather than a jurist, as most authors of such manuals were, was the reason why he devoted far more space to regulations regarding the medical profession.

According to al-Shayzarī, the *muḥtasib* was to administer the Hippocratic oath to physicians (*aṭibbā'*). The oculists (*kaḥḥālūn*) were to be qualified on the basis of the book *Ten Treatises on the Eye* written by Ḥunayn ibn Isḥāq; bonesetters (*mujabbirūn*) were to be tested on the basis of part of the medical encyclopaedia by the Byzantine writer Paul of Aegina; and surgeons (*jarā'iḥīyūn*) on the basis of a book by Galen. Another manual for a *muḥtasib* written in the next century by an Egyptian jurist named Ibn Ukhuwwa repeats nearly verbatim all the statements given earlier by al-Shayzarī.

Although these manuals specify that medical practitioners should be examined and qualified, and the treatises on medical ethics advocate examining physicians to expose charlatans, we have little evidence as to what extent and how uniformily such a practice of examination was actually carried out. There are, in fact, very few recorded instances of an examination or testing being officially administered. Three of these instances occurred in Baghdād. One was in the third/ninth century, when a false list of medicaments was given to druggists and those failing to recognize it were banished. Another was in 319/931 when, at the order of the caliph, the physician Sinān ibn Thābit ibn Qurra conducted a general examination of physicians in Baghdād, but the anectodal accounts given of this in our sources suggest that it was less than rigorous. The third occurrence was when Ibn al-Tilmīdh examined a physician who had considerable practical experience but little theoretical knowledge.[38] A fourth recorded example is that of al-Dakhwār in Syria who was charged by the Ayyūbid ruler with the examination of oculists. These meagre testimonies to testing and enforcement of standards indicate that examinations were not usual occurrences.

It is true that there were treatises written on the examination of physicians (*miḥnat al-ṭabīb*), which included questions on anatomy, humoral theory and diagnostics. Both Ibn Māsawayh and al-Rāzī, for example, wrote them. They are, however, clearly derivative from the Galenic and Hippocratic writings on the same subject. The purpose of such tracts appears to be not for the use of official examinations but for a prospective patient who wishes to determine the competency of the doctor.[39]

Also extant are many treatises written in a question-and-answer format, such as the popular *Questions on Medicine for Students* by Ḥunayn ibn Isḥāq with numerous later commentaries, or the *Discussion of the Differences Between Diseases* (*Kalām al-furūq bayna al-amrāḍ*) by al-Rāzī. It is likely that this type of literature does not reflect a system of regulation and examination (formal or informal) at all but, rather, consists of didactic pieces intended as brief study guides for students, or *aides-mémoire* to the rapid diagnosis of conditions and the basic principles of humoral medicine.

The assertion[40] that a physician was granted a license (*ijāza*) following the completion of his education is not justified by the historical documents which have thus far come to light and is a misapplication of a term to another context and period. The term *ijāza* applies to a statement placed in a student's copy of a book, stating that his instructor signifies that he has read it and is competent to teach that book himself. It was commonly granted in the fields of law (*fiqh*) and theology, especially *ḥadīth*, and frequently recorded in the medieval bio-bibliographical registers for those fields. There are isolated instances of their being given for reading a medical book, but they were not judged to be significant enough to be mentioned in the medieval biographical literature.

An example of an *ijāza* given for a medical text is one preserved in a manuscript copy of a commentary written by Ibn Abī Ṣādiq al-Nīsābūrī (d. after 461/1048) on the *Questions on Medicine for Students* by Ḥunayn ibn Isḥāq. The *ijāza* was written and signed by a seventh/thirteenth-century physician Muwaffaq al-Dīn Yaʿqūb al-Sāmirī, and reads as follows:[41]

> This part [book I] of the large *Commentary on Ḥunayn's Questions*, by the learned and eminent physician (*ḥakīm*) Ibn Abī Ṣādiq, was read before me by a student, Amīn al-Dawla Tādruṣ, son (*walad*) of shaykh Naṣr ibn Malīḥ. He read it in order to investigate its questions and to understand and ascertain [its contents] Written by Yaʿqūb al-Sāmirī, the medical practitioner (*al-mutaṭabbib*).

However, these individual cases of certified completion of texts do not suggest, much less prove, that the licensing of physicians upon completion of an approved period of training was an established practice.

While upgrading of medical standards and the exposure of frauds and tricksters was advocated by many, and the role of the *muḥtasib* no doubt did much to counteract fraudulent practices as well as to recommend texts by which to measure competency, there is at present insufficient evidence to substantiate any claim that there was an organized and centralized system of official or systematic examination and testing of physicians, even in a relatively restricted geographical area.

## SURGERY

Surgery in general tended to be viewed as something distinct from the rest of general medical care, and at least one specialized treatise was written on it. In the surgical sections of encyclopedias or surgical monographs, bonesetting (*jibāra*) and bloodletting (*faṣd*) are treated as aspects of surgery (*jirāḥa*). The term bloodletting includes four techniques: venesection or phlebotomy, cupping, scarification and leeching, though the latter two methods were less frequently used than the former two.

The major influence on surgical techniques in the medieval Islamic world was the surgical chapter from the medical encyclopaedia written about AD 642 in Alexandria by Paul of Aegina. Other Greek writings also were of importance, notably the Galenic and Hippocratic tracts and those of Antyllus written in the second century AD. The Islamic surgical writings followed these earlier tracts closely, but at the same time introduced elaborations of techniques and instrumentation, while frequently inserting actual observed cases. Furthermore, in the case of newly recognized conditions, evident particularly in ophthalmology, entirely new methods arose.

Al-Majūsī and Ibn Sīnā devoted large sections of their compendia to surgery, and while al-Rāzī dispersed his surgical observations throughout the *Ḥāwī*, he also wrote a concise chapter on the subject in his book dedicated to Manṣūr. The chapter on surgery with which Abū al-Qāsim al-Zahrāwī ended his medical encyclopaedia is particularly outstanding because of the frequent illustration of instruments and its pervading sense of personal experience. The only specialized, independent surgical manual of any importance in medieval Islamic literature was that by Ibn al-Quff in the seventh/thirteenth century, who omitted all ophthalmological procedures because he considered these the province of a specialist. Nearly all the other general discussions of surgery did include some ophthalmological practices, though not with the detail and thoroughness evident in the monographs devoted solely to ophthalmology. The tenth/sixteenth and eleventh/seventeenth-century practices in Ṣafavid Persia are derivative from these earlier Arabic ones, but some new techniques emerge, including the treating of gunshot wounds.

The lack of antisepsis and anesthesia were significant limitations on the surgery of the day. The precise extent to which sepsis was a factor in the success, or failure, of an operation is difficult to determine. The vast majority of operations were following accidents or battle wounds, in which case infection may have already set in. Only occasionally is it suggested that the patient be washed before the treatment. Following treatment, however, the area was frequently cleaned or dressed with vinegar and water, salt-water, wine, wine mixed with oil of roses, oil of roses alone or similar combinations which have varying antiseptic properties. Various aromatic herbs and resins, such as frankincense, myrrh, cassia and members of the laurel family, were used as medicaments. These also have some antiseptic properties, as do the large doses of lead and copper salts, alum, mercury and borax which were mixed with resins, oils and vinegar to make many of the recommended plasters and ointments.[42] The efficacy of such items versus the numerous sources of infection is, of course, difficult to evaluate.

Certain drugs, particularly opium, were recognized as being soporific and analgesic (*mukhaddir*), and arguments have been put forward by modern scholars[43] that such items were used to cause a person to lose complete consciousness before an operation. However, to such a practice there is no unambiguous reference in the Islamic medical literature prior to the tenth/sixteenth century when it seems, on the evidence of some Ṣafavid Persian writings, that some compounds may have been used to produce an analgesia near to the point of unconsciousness. In any case, for all the surgical procedures which will be mentioned here and which occur in the earlier

Islamic literature, no such anaesthetic is mentioned, not even the administration of wine, which, of course, in Islam would have been forbidden.

The approach to surgery was a conservative one. Cauterization was preferred to the use of the knife, which was resorted to only when all else failed. Major or invasive surgery was scarcely ever attempted. Abdominal surgery was not performed, with two possible exceptions to be noted shortly. One might be mislead by a number of illustrations in Islamic manuscripts depicting births by Caesarian sections to think that such operations were performed by medieval Islamic surgeons. Certainly Caesarian sections on a living woman for the delivery of a foetus were not performed, for such an effort would have resulted in the certain death of the woman. There is no mention in the surgical literature of such a procedure being attempted even as a post-mortem effort to save the foetus after the mother had died. In fact, post-mortem attempts at salvaging the foetus were condemned by orthodox Muslim jurists.

The illustration of the birth of Julius Caesar in a copy made in 707/1307 of a treatise by al-Bīrūnī has been frequently reproduced.[44] Over this miniature there is written in Arabic the statement: 'The reason for this was that his mother died in labour while she was pregnant with him; so her abdomen was opened, and he was taken out.' There are also illustrations of the birth of the Persian mythical hero Rustam in manuscripts of the popular Persian poem *Shāhnāmah* (*Book of Kings*) by Firdawsī. In the course of this poem, written at the end of the fourth/tenth century, it is suggested that the mother was given wine, and that the operation was performed successfully with her full recovery. However, it is merely another example of a legend attributing to its hero a miraculous birth, a common attribute in Antiquity for great men. Had such an operation been successfully performed, it would surely have been mentioned somewhere in the subsequent medical literature. In Roman law the operation was permitted on a dead woman in order to salvage the foetus, if living, or to provide for its separate burial, if dead. The fact that some Muslim jurists took occasion to condemn its post-mortem use indicates that it had been considered or even practiced, although it was not mentioned in medical tracts.

Abdominal dropsy was treated by cautery or by making an incision in the abdominal wall and then inserting a cannula for drawing off the liquid, a procedure known in Antiquity. Al-Majūsī did not approve of this treatment by paracentesis and said that he only saw it attempted once and then the patient died. Both Ibn Sīnā and al-Zahrāwī warned that it should be attempted only when the patient was very strong and all other treatments had failed. Al-Zahrāwī described a bevel-ended cannula as well as the straight one known to his predecessors.

An umbilical hernia was said to be treated by cutting around the area and then ligaturing it with a thread or silk cord. The tumor was then opened above the ligature; if the intestines were found to be in it, the ligature was to be released and the intestines pushed inwards. After tightening the ligature, the tumor was then to be cut off and the vessels ligatured. With two threaded needles the incision was to be stitched. It is doubtful if this procedure was ever performed, for no Muslim physician mentions seeing it done or modifies the procedure in any way over that given in the Byzantine tracts. Thus of the two abdominal surgeries described, the treatment for abdominal dropsy may have been performed, but clearly only very rarely and reluctantly; the second one for the umbilical hernia is likely never to have even been attempted.

Another operation described in the manuals and of great risk to the patient is a tracheotomy. This procedure, in cases of life-threatening emergency, was known to Greek physicians, though generally disapproved of and evidently seldom performed. Al-Rāzī gave a good description of the procedure, following the account given earlier by Antyllus (d. *c.* 190 AD), describing the incision of the skin, separating the edges with hooks and opening the windpipe between the two cartilages. Al-Zahrāwī stated that he had not seen the operation performed in his day. After repeating the details as given earlier by Greek physicians, al-Zahrāwī adds the following clinical report:[45]

> My own experience was this: a slave-girl seized a knife and buried it in her throat and cut part of the trachea; and I was called to attend her. I found her bellowing like a sacrifice that has had its throat cut. So I laid the wound bare and found that only a little haemorrhage had come from it; and I assured myself that neither an artery nor jugular vein had been cut, but air passed out through the wound. So I hurriedly sutured the wound and treated it until healed. No harm was done the slave-girl except for a hoarseness in the voice, which was not extreme, and after some days she was restored to the best of health. Hence we may say that laryngotomy is not dangerous.

Another traumatic operation was amputation, the subject of every surgical manual. Gangrene was the most common reason for undertaking it, in many cases no doubt following multiple fractures. Only amputation of lower joints was performed. Al-Zahrāwī warns against attempting amputation when the gangrene has spread above the elbow or the knee, and indeed such surgery could not have been successfully performed at that time. The limb was ligatured below and above the site, the site was cauterized following and sometimes during the operation, and styptics were applied. Interestingly, soporifics or analgesics are not mentioned in connection with amputations in the surgical manuals, despite their association in the popular mind with such treatment, as illustrated by the accounts given above of the amputation of ʿUrwa's foot during the reign of the Umayyad ruler Walīd I.

In the area of the perineum, incisions were made for the removal of stones in the neck of the bladder. For a calculus impacted in the urethra al-Zahrāwī introduced a technique using a fine drill inserted through the urinary passage. Incisions were also made in the groin for repair of an inguinal hernia, which al-Zahrāwī warns is a dangerous procedure. Castration was condemned by orthodox theologians, but a discussion of it, based on Greek sources, was included in medical manuals. Al-Zahrāwī said a physician should know of it if called upon to treat someone who had been castrated or if required to geld domestic animals. Ibn al-Quff did not mention the need for physicians to geld animals, but justified knowledge of the proscribed procedure by the large number of eunuchs in the court. Though castration, which carried a high risk from haemorrhage and shock, was not apparently practiced within Islamic lands, a large number of castrati slaves were imported from sub-Saharan Africa, Spain, Central Asia, India, and even China.

The removal of haemorrhoids, an ancient procedure, did not involve major incisions, but is a variation of the general treatment of tumors and growths that involved excision and cauterization. Much of the surgical literature is devoted to the removal of growths on all parts of the body. A concealed knife used to open abcesses in a manner designed not to alarm the patient appears to be an invention of al-Zahrāwī. Somewhat related to the treatment of growths was the treatment, again of ancient origin, of enlarged or pendulous male breasts by a semicircular incision on each, dissection of the fatty tissue and suturing of the incision followed by applications of styptics.

Tonsillectomies were performed in Antiquity, and the Arabic literature displays continued practice and some advancement in instruments. With the tongue held still by a tongue depressor, the swollen tonsil was held by a hook and then, according to al-Zahrāwī, removed with a scissor-like instrument with transverse blades which apparently both cut the gland and held it for removal from the throat. A hook-shaped scalpel could also be used. Then the patient was to gargle with vinegar and water. If haemorrhage followed, gargles with styptics were to be used.

Other aspects of surgery did not involve much cutting with a knife. For example, many chapters in surgical manuals were devoted to cauterization, and extraction of teeth was a common topic. It is interesting that dentistry seems to have been a part of the duties of a physician, and not a separate practice. A novel addition to the treatise by al-Zahrāwī is a chapter on the wiring and interlacing of teeth. He described how to connect to sound teeth, by means of gold or silver wire, those teeth that were loose, or had been knocked out or made artificially from ox-bone.

Circumcision of boys was described in surgical texts, though it was most frequently performed by barbers or cuppers (*ḥajjāmūn*) rather than physicians, and it was usually accompanied by many and varying rites. Circumcision of girls, on the other hand, was not discussed in the medical manuals. Female circumcision was practiced in certain Islamic countries, particularly Egypt, and was carried out by a midwife. Although performed without much ceremony, it was considered strictly a *rite de passage*, as was male circumcision, and it was not an attempt to remedy an abnormal deviation of the genitalia. Although some attention was given in the surgical literature to removing an abnormally enlarged clitoris, it clearly derived from earlier Greek accounts and does not reflect actual practice.

The treatment of wounds was of major concern in all the treatises, as was the setting of bones. The methods of suturing abdominal wounds are numerous and described in great detail. The use of animal gut for sutures is first mentioned in Arabic treatises, along with the older usage of wool, linen and silk. Reducing tables were employed to extend the limbs so as to reduce dislocations and fractures. An injured limb was bandaged and a splint applied, following the well-established Greco-Roman methods. Among other bone-setting procedures were the repair of a broken nose and the treating of a skull fracture by trepaning with a non-sinking drill which was outfitted with a protruding collar designed to prevent it from sinking into the underlying meninges.

Gynaecological matters always occupy a chapter in surgical tracts, even though the treatises were written by men who would have been unlikely to operate directly on women in Islamic society. As al-Zahrāwī noted in connection with lithotomy in a woman:[46] 'The treatment is indeed difficult and is hindered by a number of things. One is that the woman may be a virgin. Another is that you will not find a woman who will expose herself to a [male] doctor if she be chaste or married. A third is that you will not find a woman competent in this art, particularly not in surgery ... If necessity compels you to this kind of a case, you should take with you a competent woman doctor. As these are very uncommon, if you are without one, then seek a eunuch doctor as a colleague, or bring a midwife experienced in women's ailments or a woman to whom you may give some instruction in this art. Have her with you and bid her to do all that you enjoin.'

Much of the gynaecological material is drawn from Greek sources, but there are considerable elaborations and innovations. The gynaecological section frequently begins with general instructions on training midwives to perform unusual deliveries, and there is considerable concern for extracting dead foetuses and removing the afterbirth. Variations in the design of a vaginal speculum, or dilater, were introduced, and forceps were described by al-Zahrāwī, though not for use in live births.

Throughout the surgical writings, the Islamic physicians display a sensible and humane reluctance to undertake the riskiest and most painful operations. That physicians were well aware of the discomfort they inflicted on patients is illustrated by the following account of the very experienced al-Rāzī refusing to submit himself to surgery. Al-Rāzī studied too much, and, according to al-Bīrūnī:[47]

> That was one of the things, along with his fondness for beans, which impaired and harmed his vision, for he concluded his life in blindness, so that 'he shall be blind in the world to come' [as the *Qur'ān* XVII, 74 says], because a cataract descended over his eyes at the close of his life. An associate of his school days came to him from Ṭabaristān in order to treat him. So he [al-Rāzī] asked him what the nature of his treatment was to be, and he told him in detail. Abū Bakr [al-Rāzī] replied: 'I acknowledge that you are the most outstanding of couchers of cataract (*qaddāḥūn*) and the most learned of oculists. You know, however, that this operation is not without pain which the soul loathes and long-drawn-out discomfort which men find wearying. But perhaps [my] life may be cut short and the time of death be near; and then it is repugnant to someone like myself at the end of his days to choose pain and discomfort over repose. So depart, with thanks for what you intended and endeavored to do.' And he was generous in his reward to him. Then his days were not long after that, and he died at Rayy on 5 Shaʿbān 313 [26 October 925] at the age of sixty-two lunar years and five days, which by solar reckoning is sixty years, two months, and a day.

## OPHTHALMOLOGY

The only area, other than pharmacology, that could truly be called a speciality was ophthalmology, and for this area there developed an extensive specialist literature. Islamic physicians displayed particular concern and skill in the diagnosis and treatment of eye diseases, perhaps because blindness was the major cause of disability throughout Islamic lands. Nearly every medical compendium has chapters concerned with eye diseases, but the most comprehensive coverage is to be found in the large number of monographs devoted solely to the subject. In the third/ninth century Ḥunayn ibn Isḥāq, as had his master Ibn Māsawayh, wrote monographs on ophthalmology including the influential *Ten Treatises on the Eye* which, though based to a large extent upon Greek sources, already showed considerable advancement in knowledge over that in the extant Byzantine treatises. One of the most highly regarded of all the ophthalmological manuals was that covering 130 eye ailments written by ʿAlī ibn ʿĪsā (d. 400/1010) who practised in Baghdād. A contemporary of his was ʿAmmār ibn ʿAlī al-Mawṣilī, who was originally from Iraq but moved to Egypt where he dedicated his only writing, a treatise on eye diseases, to the Fāṭimid ruler al-Ḥākim who ruled from 386/966 to 411/1020. The latter work only discusses forty-eight diseases, but contains some fascinating clinical cases and adaptations of surgical instruments.

The treatise by ʿAmmār begins with an interesting comment on the oculists of his day:[48]

> When I observed the assembly of medical people in the hospitals, there were oculists and others, some of whom did not read or write. Among them was an experienced[49] man who said he inherited a remedy from his father which he had envisioned in his sleep! If someone questions them about the science of the eye (*ʿilm al-ʿayn*), they do not comprehend the question and do not know the answer because of their lack of understanding, the wandering of their minds, and their neglect of studying the science. They do not know anything except trying things for the first time on peoples's eyes, and they treat diseases which require styptics by things which resolve, and those which need loosening agents by styptics. They are always being disrespectful and paying attention to themselves [rather than] to one of the people of the sciences, in an arrogant and vain manner, and so they are always making mistakes. So I wished that I might draw near to God Most High, seeking his reward and his abundant favors, by composing a collection of what I had experienced and practiced regarding the science and art of the eye, and its tunics, humors, and muscles, and its problems and answers, and all of its diseases, and its therapy, both that with drugs and that with surgery, because my ability in surgery and practical procedures (*ʿamal*) is unequalled by any of the people of this art whom I have observed.

In discussing the treatment of a cataract, ʿAmmār presents four detailed clinical cases and a needle instrument of his own design. In treating cataracts, an ancient technique called couching was commonly employed. This method, coming possibly from India into the Hellenistic world and then into Islamic lands, consisted of pushing the lens of the eye out of the way by inserting into the eye a needle or probe through the edge of the cornea. Infection and glaucoma were the major causes for failure. Considering that an untreated cataract inevitably results in blindness, and in view of the success rate for couching being approximately four in ten,[50] it is obvious why couching found widespread acceptance.

ʿAmmār designed a hollow cataract needle, made of metal and pointed, for the removal of the cataract from the eye by suction. This hollow tube is mentioned by later ophthalmologists, and the removal of a cataract by suction using the hollow needle was actually observed by the oculist and historian Ibn Abī Uṣaybiʿa being used about 627/1230 in the Nūrī hospital in Damascus, although the eighth/fourteenth-century Egyptian oculist Ṣadaqa ibn Ibrāhīm al-Shādhilī said he had no opportunity to see its use.

There is evidence that in some locales there were people who did nothing but couch cataracts; they were probably itinerant and not highly trained in other medical matters. For example, the physician Quṭb al-Dīn al-Shīrāzī said in his commentary on Ibn Sīnā's *Qānūn* written in Shīrāz in 682/1283:[51] 'I practiced manual techniques appertaining to medicine and ophthalmology, such as bloodletting, suturing and fastening, everting [the eyelid] and the removal (*laqṭ*) of pterygium and pannus, and other things, all except the couching operation (*qadḥ*) which was not befitting that I should perform.'

Impressive surgical and diagnostic skill is displayed in the treatment of trachoma, the major cause of blindness, and its sequelae trichiasis, entropion and pannus. Trachoma itself was treated by everting the eyelid and scraping the interior with a selection of scrapers. Intricate surgical procedures were used for dealing with trichiasis and entropion, i.e. the superfluous and ingrown eyelashes and rolled in eyelids. Trachomatous pannus, a vascularization which invades the cornea, was not apparently known to the Greek physicians, but was clearly described and treated by peritomy by even the earliest of the Islamic doctors and was recognized to be a sequela of trachoma. The surgical treatment of pannus employed an instrument for keeping the eye open during surgery, a number of very small hooks for lifting and a very thin scalpel, couching needle or scissors.

Pterygium, which is a triangular-shaped encroachment of the bulbar conjunctiva onto the cornea, was described by Hellenistic and Islamic physicians and excised by using the same instruments as in pannus. Both surgical procedures are intricate and painstaking and cause considerable pain to the patient, yet both appear to have been occasionally, if not routinely, performed.

When describing the surgery for trichiasis, pannus and pterygium, ʿAlī ibn ʿĪsā employed a word, *tanwīm*, which has caused much debate among scholars as to whether it means to put the patient to sleep or merely to make the patient lie down.[52] However it is interpreted, it is instructive that no other specifics are given, and the word is not used in similar contexts and is dropped from later writer's discussions of the subject, for they apparently either did not understand the word or thought it insignificant.

## ANATOMY

Human anatomical dissection was not a pursuit of medieval Islamic society any more than it was in the contemporaneous Christian lands, due as much to general cultural taboos and customs as to specific religious strictures.

Consequently, experimental anatomical discoveries are not to be expected nor are they to be found. None the less, there were two noteworthy contributions to the history of human anatomy made by medieval Islamic scholars.

The most notable is the pulmonary circulation described by Ibn al-Nafīs, who reasoned that it must be so regardless of what Galen had stated. Galen had asserted that between the two ventricles of the heart there had to be a passage, but that it was not visible. Ibn al-Nafīs contended that it was not there to be seen and consequently that blood in the right ventricle must reach the left ventricle by other means, namely by way of the lungs. Ibn al-Nafīs stated this insight in his commentary on the anatomy of the *Qānūn*. But this particular work was not as readily available to the medical community as his commentary on the complete *Qānūn*, or his epitome of it, and his formulation of the theory of pulmonary circulation remained almost unknown in Islamic writings, there being only two later, eighth/fourteenth-century, writers who seem to have known of it.[53] Nevertheless, it seems likely that it did influence European anatomical theories.

The second instance resulted from a chance observation. The versatile scholar ʿAbd al-Laṭīf al-Baghdādī, who taught medicine in Damascus, wrote a description of Egypt which included his observations on the famine which occurred there in 597/1200. During this time he happened to see a very large number of skeletons, and finding himself with the rare opportunity of being able to examine a good number of them, he concluded that Galen had been incorrect regarding the formation of the bones of the lower jaw and sacrum. This observation went unnoticed in subsequent literature, possibly because of its being in a book on descriptive geography.

In both of the cases just cited the physicians questioned neither the basic tenets of Galenic thought nor its universal applicability, though they did correct certain aspects of it. The anatomical concepts in medieval Islamic medicine remained fundamentally Galenic, as did the medical theory, despite considerable surgical experience on the part of many physicians.

Many scholars in Islam lauded the study of anatomy, primarily as a way of demonstrating the design and wisdom of God. Typical of such sentiments is that said to be one of the sayings of the noted Spanish philosopher and physician Ibn Rushd (d. 595/1198) known in Latin as Averroes:[54] 'Whoever is occupied with the science of anatomy increases his belief in God.' What is meant by the 'science of anatomy' (*ʿilm al-tashrīḥ*) in such statements is not the active dissection of an animal in order to determine its structure, but rather the elaboration of the ideas of Galen regarding animal structure and function. Galen had presented the subject, particularly in his *On the Usefulness of the Parts*, in a highly teleological way, with constant emphasis on structure, function and purpose demonstrating the design of the Creator. This approach to describing anatomy found a very receptive audience among Islamic philosopher-physicians.

However, a forceful appeal to physicians to undertake anatomical dissections is found in a treatise written for Saladin by one of his physicians, Ibn Jumayʿ al-Isrāʾīlī. This tract is concerned with the deplorable state of medicine at the time and proposed measures to correct it. Among other things, Ibn Jumayʿ lists the following as one of the requirements of a good doctor:[55]

> He also requires the enumeration of the parts of the human body part by part and the knowledge, gained through experience (*ḥiss*) and observation (*mushāhada*), of the characteristics of the nature of each one of them with regard to the colour, the normal state, and the like; [and knowledge] of its structure, that is, its shape, its smoothness or its roughness, whether there is a cavity or duct in it and what this cavity or duct contains; of the extent of its size and the number of its component parts and the nature of each component, if it has component parts; of its position, that is, its position in the body and whatever association and connection there may be between it and other parts; and of its function and useful purpose or purposes for which it is needed.
>
> Pursuit of these things by experience only comes about through the anatomical dissection of human bodies (*tashrīḥ al-abdān al-basharīya*). But anatomical dissection of these bodies is not [done] with ease and convenience at all times, [and] it does not suffice for the knowledge of these matters unless it is preceded by extensive practice in the anatomical dissection of other similar animals whose parts for the most part are like the parts of man, such as apes, [and] in the presence of instructors who are skilled in it, as the excellent Galen clearly and concisely outlined.

As explicit an appeal for human post-mortem dissection as this appears to be, it is none the less difficult to tell how much it represents merely a reworking of the statements and recommendations of Galen and how much it reflects actual practices current in Egypt in the sixth/twelfth century.

All the medical compendia had sections on anatomy, and a few monographs were devoted to the topic. Outside of some schematic illustrations of the eye or diagrams of cranial sutures, the Arabic medical treatises do not have anatomical illustrations. There are, however, sets of full-page anatomical drawings with mixed Persian–Arabic labelling that illustrate arteries, veins, nerves, bones, muscles and a pregnant woman. These illustrations appear to maintain the Greco-Roman traditions in anatomy and are closely related to Latin anatomical diagrams dating from as early as the twelfth century AD. There are many copies of these illustrations, most of them accompanying a Persian text on anatomy written in 798/1396 by Manṣūr ibn Muḥammad ibn Aḥmad ibn Yūsuf ibn Ilyās; both the text by

Ibn Ilyās and the sets of anatomical diagrams are the subject of much current research.

## POPULAR MEDICINE

The medical practice of the professional, learned physicians, based on medical theory and natural philosophy inherited from Hellenistic and Byzantine writers, was supplemented by practices based on what today we would call popular magical practices and astrology. These reflect ancient beliefs and customs which long predate the advent of Islam to the region. The reliance at times on astrology and magic can be seen at all levels of the society, though it is most evident among the lower strata of society, especially in rural areas, since outside the large urban centres there would have been little other care available. One of the most obvious uses of charms and incantations was to protect against epidemics, whose occurrence was devastating, unpredictable and little understood. In such dire times it is to be expected that many people (more than indicated by written documents) would attempt to propitiate the evil forces in a hostile world and gain the blessing and protection of God. This could be done through certain incantations or prayers to be said at specified times or through amulets and talismans having special inscriptions which would both protect and alleviate. Certain *sūras*, or chapters, of the *Qur'ān* were considered especially beneficial; magic squares were combined with other sigla and magic alphabets to form amulets. Treatises known as plague tracts contained, among other things, texts for such supplicatory prayers and amulets, and, in addition, there were a vast number of general manuals written on incantations, prayers and talismans for all manner of illnesses and misfortunes and for aiding childbirth.

A widespread belief which has persisted for many centuries is the belief in the evil eye – i.e. individuals by glancing at others or catching their eyes can, sometimes unwittingly, exert evil forces and bring misfortune on the object. The result is believed to be any number of misfortunes including sudden death, but the most common is a gradual wasting illness. Numerous directions for making items to ward off the consequence of the evil eye are to be found in medieval writings.

The services of fortune tellers and diviners offered an alternative for many to the diagnosis and prognosis of the established medical community. Thus itinerant astrologers, geomancers and other prognosticators were consulted to determine the cause of an illness and what the outcome would be, whether recovery would be soon or only after much suffering or whether the illness might even bring death. From the nature of astrologies, geomancies, chiromancies and similar tracts, it is evident that medical problems were one of the major reasons for consultation, as well as determining if a woman was pregnant, the sex of the child and whether the delivery would be an easy one. Although today we tend to attribute such an approach to medicine to the less privileged, none the less, it is a fact that prognosticators of various types were in the entourage of every ruler. For example, when the Mamlūk ruler al-Nāṣir Muḥammad ibn Qalā'ūn became ill with diarrhoea in 741/1341, he consulted astrologers and geomancers as well as physicians.[56]

Further evidence that such practices were not the sole domain of the poor can be found in the magic medicinal bowls and so-called 'poison cups' made for Ayyūbid and Mamlūk rulers in the sixth/twelfth and seventh/thirteenth centuries. Many museums and private collections contain such bowls and cups, the earliest made in Syria for specific rulers. These metal bowls were engraved with magical symbols, animal figures, circles, magic squares and Qur'ānic verse. According to inscriptions on them, they were useful against colic, rabies, scorpion stings, nosebleed, stomach-ache, headache and even trachoma, and would assist in childbirth and protect against all types of poison. The patient, or someone acting as his agent, was to drink from the bowl in order to be cured, sometimes following specific instructions, such as drinking hot water for colic, or saffron water if difficult labour was to be avoided. Curiously, there appears to be no mention of such devices in the literature of the period.

Popular Ṣūfī spiritual leaders often had considerable local followings because of their skills in supernatural healing. A dervish or experienced elder would recite prayers and Qur'ānic verse, sometimes employing dreams to determine treatment or holding ritual ceremonies. Spiritual medicine (*ṭibb ruḥānī*), which sometimes was indistinguishable from magic, was not as much a part of Sunnī society as it was of Ṣūfī culture. Throughout the society there were wise women known for their healing skills and consulted for problems of childbearing, dispensing herbs and amulets. They generally treated a variety of ailments, frequently using methods of sympathetic magic, such as keeping articles of clothing.

The writings of the highly learned physicians were not devoid of beliefs in sympathetic magic, occult powers and astrology. For example, al-Rāzī in the *Ḥāwī* records the eating of a scorpion or squashed earth worms to break up bladder stones, or the wearing of an unwashed and sweaty garment which had been worn by a woman in labour to cure a particular type of fever.[57] Many a sympathetic remedy was recommended for easing the pains of childbirth – the use of a magnet being one example. As for astrology, many physicians were outspoken advocates, such as Ibn Riḍwān and al-Rāzī. The positions of the stars and planets could influence the crises of illnesses, determine the best time for bloodletting and other remedies and serve as aids to diagnosis and prognosis of conditions. Others, such as Ibn Sīnā, wrote tracts refuting astrology. Yet even those who were not overt advocates of astrological and magical practices nearly all adhered in a fundamental way to what might be termed an astrological world view, in which the events of the microcosm were seen as mirroring and hence being related to those in the macrocosm. Such a view of the cosmos had permeated, to one degree or another, all learned thought well before the advent of Islam and continued to do so for centuries. Throughout the society, in varying degrees, there was room for popular explanations and cures of illness alongside the more learned, some might say more rational, approaches.

## CONCLUSION

Having given examples of various facets of medieval Islamic medical care, the question then arises as to why this energy and vitality did not continue unabated until modern times. The explanation is a complex one, and only a few of the reasons can be suggested here. As the Islamic world became increasingly fragmented, the patronage and accompanying prestige and security enjoyed by the leading physicians declined. Spain was lost, European crusaders made repeated invasions into the central lands, and in the seventh/thirteenth century the Mongol invasions from the east disrupted life. The Mamlūks in Egypt managed to hold off the invasions of the Mongols, and it is no doubt for that reason that the medical community there remained active for a longer period of time than elsewhere, with the exception of Ṣafavid Persia.

The hospitals were dependent upon charitable endowments for their maintenance, and with time these funds became insufficient to support them. Consequently the hospitals tended to deteriorate and eventually fall into disuse, except for a few, such as the Nūrī hospital in Damascus, which continued to operate as a hospital until the end of the nineteenth century. With the expansion of the population the remaining hospitals and dispensaries proved inadequate.

From the later fifth/eleventh century onward, the alliance of medicine with philosophy, which had been inherited from the Hellenistic world, became detrimental. The religious and legal framework of Islam gradually shifted to a more conservative position, and it was perceived that the ideas of physicians such as Ibn Sīnā on the nature of revelation and creation and similar matters were incompatible with Islamic orthodox beliefs. Consequently, some Muslim mystics such as the Ṣūfī theologian al-Ghazālī (d. 504/1111) reacted strongly against these medical writings. These attacks were really against philosophical points rather than medical ones, but since learned medicine was so closely allied with philosophy, medical thought itself was affected and development inhibited. As theologians came to deny the certainty of knowledge outside the realm of revelation and to question previously held notions of causation, then the examination of patterns in nature became an inappropriate topic for human consideration. And some viewed the practice of physicians as interference with God's counsels, although others held that the Prophet Muḥammad had through his statements sanctioned some medical practices. Such an intellectual environment was basically limiting to the development of medical practice and particularly to theoretical innovation. Yet, in the event, internal quarrels between different sects and schools of theology allowed development of scientific and medical thought to continue, though at an increasingly diminished state, for a considerable period of time.

Despite the somewhat constraining atmosphere, the learned medical community remained quite active through the eighth/fourteenth century, particularly in Syria and Egypt, but within two more centuries nearly all trace of serious scholarly activity had faded. Only in Ṣafavid Persia – i.e. in Iran of the sixteenth and seventeenth centuries – and at the Ottoman court in Istanbul, did medical compilers and commentators still continue to write and organize with some degree of originality.

The theoretical foundations of the art in the medieval and early modern Islamic world remained resolutely Greek based, with the physicians by and large satisfied to collect, organize, analyse and make more useful that which their predecessors had written, limiting the corrections to small details. It is in the more practical aspects of medical practice – the recording of case histories, the interest in symptomatology resulting in much fuller accounts of certain diseases, the refinements in surgical techniques and other aspects of therapeutics – that the vitality and creativity is to be seen, while the concern shown by medieval Islamic society for matters of public health is especially remarkable, particularly in the development of the hospital system.

## NOTES

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1 For a discussion of medical pluralism in medieval Islamic society see Dols (1984a: 39–41).

2 Ibn Khaldūn, *al-Muqaddima*, ed. Quatremère, vol. 3, pp. 118–19. The translation is that, somewhat revised, by Franz Rosenthal in Ibn Khaldūn, *The Muqaddimah, An Introduction to History*, Bollingen Series 43, 2nd edn, Princeton, 1967, vol. 3, p. 150.

3 Ibn Qutayba, *Kitāb al-maʿārif*, p. 222.

4 Ibn al-Jawzī, *Dhamm al-hawā*, pp. 221–2. For al-Iṣbahānī, see al-Iṣfahānī [*sic*], *Kitāb al-Aghānī*, p. 241. See also Ullmann (1978b: 50).

5 Walzer (1962: 15).

6 Al-Rāzī, however, begins his treatise by defending Galen against those who said that Galen did not know of smallpox. Al-Rāzī refers to passages in three Galenic treatises in which he says that Galen referred to smallpox (see al-Rāzī, *A Treatise on the Small-Pox and Measles*, English translation by W. A. Greenhill, p. 144 note D). In extracts made from Arabic translations which al-Rāzī collected in his *Ḥāwī*, al-Rāzī occasionally misread Arabic words; this is an easy error to make since a slight change in points in the Arabic can change a word drastically. For examples, see Savage-Smith (1984).

7 Al-Rāzī, *Rhazes de variolis et morbillis*, pp. 106–18. The translation is that by Greenhill but with substantial modifications (Rhazes, *A Treatise on the Small-Pox and Measles*, pp. 51–3). The translation of Greenhill, in turn, shows considerable dependence upon that by Thomas Stack to be found on pp. 97–204 in Richard Mead, *A Discourse on the Small-Pox and Measles.*

8 Garum (*murrī*) is a salted fish product, usually a fermented fish sauce made of fish intestines, salted and macerated into a paste. The exact composition varied depending upon the type of fish or the parts used. The significance of specifying Nabatean is unknown. For a discussion of garum in Arabic treatises as well as some Greco-Roman ones, see the notes by K. Garbers to al-Kindī, *Kitāb Kīmiyāʾ*, pp. 282–3, no. 79; and Robert J. Curtis (1984).

9 Al-Rāzī, *Kitab al-Ḥāwī*, Part 16, p. 201. The translation is that of the present author; cf. Max Meyerhof (1935b: 343–4, no. 24).

10 Following the text given by Meyerhof (see note 9) which reads *min ḥalqihi*, 'in his throat', while the Hyderabad text reads *maʿ khilfa*, 'with a difference'.

11 Al-Rāzī, *Kitāb al-Ḥāwī*, Part 16, pp. 202–3. Translation is that of the present author; cf. Meyerhof (1935b: 344–5, no. 27).

12 Oxford, Bodleian MS Marsh 156, fol. 167a lines 6–12; Iskandar (1962a: 238–9). Translation is that of the present author.

13 Pinès, 'Al-Rāzī', in *Dictionary of Scientific Biography*, vol. 11, pp. 325–6.

14 Al-Majūsī, *Kitāb Kāmil fī al-ṣināʿa*, vol. 1, p. 5 line 3 to p. 6 line 3. Translation is that of the present author.

15 Hamarneh and Sonnedecker (1963: 51).

16 *Qānūn* I,1,i,1. For the text see Ibn Sīnā, *al-Qānūn fī al-ṭibb*, New Delhi edition (1982: 33–4).

17 Ibn Sīnā, *Qānūn*, IV,l,ii. Text used was Ibn Sīnā, *al-Qānūn fī al-ṭibb*, edition published in Baghdad, vol. 3, p. 68, lines 26–32); see also the edition published in Rome (1593: 36).

18 Ibn Sīnā, *Qānūn*, I,4,v,30. For the text see the edition published in New Delhi (1982: 332–3) and the edition published in Rome (1593: 111) where it is *faṣl* 31.
19 Michael McVaugh in Grant (1974: 715, note 1).
20 Oxford, Bodleian MS Marsh 390, fol. 1a, lines 2–9; Iskandar (1967: 35–6). Translation is that of the present author.
21 Oxford, Bodleian MS Marsh 390, fol. 2a, line 18 to fol. 2b, line 8; Iskandar, (1967: 36–7). Translation is that of the present author.
22 See Dols (1984a: 10, note 38).
23 Heinen (1982: 35–6).
24 Bürgel (1976: 50).
25 Ibn Khaldūn, *al-Muqaddima*, ed. Quatremère, vol. 3, p. 119. *The Muqaddimah*, English translation, vol. 3, pp. 150–1. Translation is that of Rosenthal, slightly revised.
26 There is in fact one manuscript copy of Ibn Abī Uṣaybiʿa's treatise which does include a short biography of Ibn al-Nafīs. A manuscript in Damascus, Ẓāhirīya MS 4883 ṭibb, fol. 104b, contains a very brief biographical sketch on the last folio, but since this notice of Ibn al-Nafīs is missing in all other copies, it is possible that it was added at a later date. It is an undated, apparently rather recent, copy.
27 Iskandar (1967: 42–9 and 40, note 2).
28 Los Angeles, University of California, Bio-Medical Library, Near Eastern Collection 1062, MS 80, colophon dated 640/1242. See Iskandar, 'Ibn al-Nafīs', in *Dictionary of Scientific Biography*, vol. 9, pp. 602–6.
29 Al-Majūsī, *Kitāb Kāmil fī al-ṣināʿa*, vol. 1, p. 9, lines 2–6.
30 Rosenthal (1978: 479).
31 Goitein (1963: 187).
32 Rosenthal (1978: 481–4). See also Goitein (1963: 191–2); Dols (1984a: 37–9); and Biesterfeldt (1984).
33 Al-Rāzī, *Kitāb al-Manṣūrī*, vii, 27; text edited by Iskandar, pp. 487–92. Translation is that by Leiser (1983: 66–7).
34 Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ*, vol. 2, p. 244, lines 20–7.
35 ʿAbd al-Qādir al-Nuʿaymī, *al-Dāris fī taʾrīkh al-madāris*, vol. 2, pp. 133–8. Compare Ibn Shaddād, *al-Aʿlāq al-khaṭīra*, p. 266; and Leiser (1983: 58).
36 See Meyerhof and Schacht (1968: 18); and Dols (1984a: 36, and note 188).
37 Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ*, vol. 2, p. 242, lines 7–8.
38 For these three instances see Dols (1984a: 32–3, and note 166); and Leiser (1983: 48–75).
39 However, al-Shayzarī, in his manual for the *muḥtasib*, does state: 'The *muḥtasib* ought to test the physicians by what Ḥunayn [ibn Isḥāq] discussed in his book known as *The Examination of the Physician* (*Miḥnat al-ṭabīb*); as for the book *The Examination of the Physician* by Galen, there is scarcely one [physician] who can stand up to what he [Galen] requires of them'. See al-Shayzarī, *Nihāyat al-rutba*, pp. 99–100.
40 For example, see ʿĪsā (1928: 16–23; and edition published in Damascus, 1939: 41–3); and Hamarneh (1964: 167). For further references, see Dols (1984a: 33, note 167). In fifth/eleventh-century Egypt, a police certificate (*tazkiya*) of good conduct was required for practice; see Goitein (1971: 246–7, 250).

41 Oxford, Bodleian MS Marsh 98, fol. 208a. The translation is (with a slight emendation) that of Iskandar given in 'Ḥunayn ibn Isḥāq', in *Dictionary of Scientific Biography*, vol. 15, p. 239.
42 For these antiseptic properties, see Majno (1973: 186–8, 217–21, 369); and Riddle (1985: 48–9, 79, 145, 152).
43 Elgood (1970: 166–9).
44 Edinburgh University Library, Oriental MS 101, fol. 16a; reproduced, for example, in Elgood (1970: 255), and Ullmann (1978b: plate 3 opposite p. 34). For the history of the operation, see Trolle (1982).
45 Albucasis, *On Surgery and Instruments*, pp. 338–9. Translation is that of Spink and Lewis, with slight emendations.
46 *Ibid.*, pp. 420–1. Translation is that of Spink and Lewis.
47 Kraus (1936: 5–6). Translation is that of the present author.
48 Cairo, Dār al-Kutub, MS ṭibb Taymūr 100, p. 244; Leningrad, Institut Naradov Azii, MS C 875, fol. 196b; and Escurial, Arabic MS 894, fol. 92b. The text followed is generally the Cairo manuscript with an additional sentence found in the Leningrad and Escurial copies; translation is that of the present author. Cf. Meyerhof (1937: 38–9).
49 Reading *mujarrab*; however, *mujarrib* or 'experimental' is equally likely, in which case it would have been used in the pejorative sense of Empirik, i.e. a person who indulged in a crude empiricism, an approach to medicine opposed by Galenists.
50 Majno (1973: p. 531, note 235); and Feigenbaum (1960b: 319–23).
51 Iskandar (1967: 43) where the text is given. Translation is that of Iskandar, with a slight emendation.
52 Feigenbaum (1960a); Meyerhof (1936: 55, 63); Wood, Casey, A. (1936: xx–xxii, 97, 138–9, 146); and Elgood (1970: 167–8).
53 Iskandar (1967: 47–50).
54 Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbā'*, vol. 2, p. 77, lines 13–14.
55 Ibn Jumayʿ, *Treatise to Ṣalāḥ al-Dīn*, p. 14, section 25. The translation is that of the present author, which varies slightly from that given by Fähndrich on p. 11.
56 Ullmann (1978b: 112, and note 16).
57 *Ibid.*, p. 109.

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# 28

# *The influence of Arabic medicine in the medieval West*

DANIELLE JACQUART

The medieval West is indebted to the Arab world for simultaneously passing on primary Greek sources and the contributions of original Arabic texts. The latter contributions are particularly worthy of our attention. The influence of Arabic medicine has proved to be of critical importance, though often elusive, since it is so interwoven with the Greco-Latin legacy. Rather than quickly drawing up an inventory of selective contributions, it seems preferable to elucidate the most important major themes, i.e. to follow the role played by certain key texts. This endeavour cannot be applied here to all possible subject areas: we leave to one side the science of surgery and materia medica, to limit ourselves to the study of medicine in the strictest sense of the word, paying greatest attention to those questions of more general import. The Arabic texts became available mainly through two successive waves of translations, the first entering southern Italy in the second half of the eleventh century, the second entering Spain about a hundred years later. These two groups tended to translate as many texts as possible into Latin, thus offsetting the poorness of scientific information which was prevalent in the West. In the thirteenth century the translators were more selective and dedicated their efforts to a particular author or to a particular subject.

## THE FIRST WAVE OF TRANSLATIONS: THE ESTABLISHMENT OF WESTERN MEDICAL DOCTRINE

Although it is impossible to establish with certainty, it seems that the first medical work translated from Arabic was the *Isagoge Iohannitii*, an incomplete version of the *Masāʾil fī al-ṭibb* by Ḥunayn ibn Isḥāq. The strongest arguments in favour of this assumption are, on the one hand, the presence of this tract in manuscripts at the end of the eleventh century and, on the other hand, the still fluctuating nature of even the most fundamental medical terminology which it uses. The *Isagoge* can be related to the works of Constantine the African (d. before 1087), a translator whom posterity has not ceased to vilify, from his immediate successors to today's modern critics, owing to the unfaithful way in which he treated the original texts. Recent studies invite us to qualify this point of view: one notes the omissions, the abridgements, the minor suppressions, but his translation does render the literal sense of the Arabic.

Through Constantine Arabic works arrived in the Latin West under a Grecian mask. The translator did not hesitate to recognize the works which he translated into Latin as his own, hoping to present them as a rediscovery of Greek science, of which he considered himself to be the *coadunator*, i.e. the co-ordinator. This penchant for Hellenization is illustrated by the choice of titles, such as *Isagoge* or *Pantegni*, the latter concealing beneath the reference to Galen's *Techne*, the *Kāmil al-ṣināʿa al-ṭibbīya* of ʿAlī ibn al-ʿAbbās al-Majūsī. Strangely enough, only the works of Isḥāq ibn Sulaymān al-Isrāʾīlī are presented under the name – admittedly Latinized – of their real author (Isaac Israeli). The list of translations attributed or attributable to Constantine the African (see Table 28.1, pp. 981–4) calls for several observations. In the first place the important figures of Arabic medicine, such as al-Rāzī and Ibn Sīnā, are absent. The Constantinian corpus consists on the one hand of two syntheses based essentially on Alexandrian Galenism, Ḥunayn's *Masāʾil* and the *Kāmil* by ʿAlī ibn al-ʿAbbās, and on the other hand of works whose authors came from North Africa and which were once linked with the intellectual activity of Kairouan (al-Isrāʾīlī, Isḥāq ibn Imrān, Ibn al-Jazzār). The biography of this translator, still coloured by legends and mysteries, explains the latter peculiarity: it seems well established that he was born in Carthage, even if this does not imply that he was a Muslim and that he converted to become a monk at Monte Cassino. The possibility of his having Christian roots cannot be excluded. Through Constantine's translations the first contact that the Latin West had with Arabic thinking reflects the state of medical teaching in North Africa in the tenth century.

The importance of this first inroad made by Arabic medicine into the south of Italy must be measured first of all by referring to the state of medicine which already existed there. The Latin texts which were in circulation in the High Middle Ages essentially consisted of clinical descriptions, rules for establishing a diagnosis, recipes and diets. The syntheses of later Antiquity such as the *De medicina* of Cassius Felix or the fragmentary translation of the *Synopsis* of Oribasius presented a description of illnesses and remedies, without systematically recalling the underlying physiological theory. Medicine thus appeared as an operating technique, close to empiricism, the principal custom of therapeutist monks. Some excerpts from the substratum of theory were nevertheless present in the Ravennate versions of Alexandrian commentaries. It is probable that these excerpts were known in Salerno, a privileged receptive environment for Constantine the African's translations. The origins of the famous school are also tinged with mystery, but its reputation appears established in the tenth century. That there was a demand, in these surroundings, for acquisition of extensive theoretical knowledge is scarcely in doubt; a contemporary of Constantine, Alfanus of Salerno, translated from the Greek the *De natura hominis* by Nemesius of Emesa, which linked medicine firmly with natural philosophy. In the same perspective, the major contribution of the first Arabic translations, in addition to the mass of information that they conveyed, was to help medicine to become established as a science.

Before discussing more particularly the effect of the Constantinian translations in the Salernitan environment, it is appropriate to recall another of the initial areas of their diffusion – the Chartrian environment. There is evidence that part of the Constantinian corpus was circulated and commented on in Chartres, a privileged place in the intellectual life of the twelfth century. William of Conches cited the *Isagoge* and the *Pantegni* here in the years 1120–30 in his *Philosophia mundi*, and again a little later in his annotations to Plato's *Timaeus*. These citations allow us to judge what was perceived as new in the texts introduced by Constantine the African; even though William of Conches's medical knowledge remained on a superficial level, he had intuition about what would provide an impetus to Western thought. One of the areas which particularly benefited from Arabic medical studies was ophthalmology. Without entering into a detailed description of the anatomy of the eye, William of Conches referred to the source of information which he considered to be the best: 'If one would like to know the name of the humours and the tunicae, one should read the *Pantegni*' (*Philosophia mundi* IV, 25). We note that the Chartrian author did not refer to the *De oculis*, stemming from the *Tarkīb al-ʿayn* by Ḥunayn ibn Isḥāq, although this translation was widely known. As David Lindberg emphasizes, the presentation offered by Ḥunayn, in the pure Galenic tradition, had a direct or indirect influence on Western ophthalmology until the seventeenth century. At the end of the twelfth century the *De oculis* by Benvenutus Grapheus of Salerno contributed to the wider diffusion of Ḥunayn's presentation of the anatomy and physiology of the eye; and also finds here the first Western descriptions of the reduction of a cataract. In the Middle Ages the theory of vision underwent many reorientations due to other Arabic contributions and the controversies surrounding extramission and intromission; whilst on this subject one should note that the work of Ibn al-Haytham (the Alhazen of the Latins) was particularly used in non-medical treatises dedicated to optics. On this point I refer to the works of David Lindberg.

Another new idea which William of Conches retained from the *Pantegni* concerns the development of mental faculties in the brain: 'three [qualities] unite to create perfect wisdom: the ability to grasp, the ability to distinguish what has been grasped and the ability to retain this knowledge in the memory. Similarly in man's head there are three ventricles: one in the prow, another in the stern and a third in the middle' (*Glosae super Platonem*, p. 74). Traces of this three-way partition of the brain were present in several works pre-dating the Constantinian corpus and an expose on mental faculties can be found in the *De natura hominis* by Nemesius of Emesa. However, the explanation given in the *Pantegni* had a decisive influence, which can be measured by the number of occurrences of the words 'prow' and 'stern' (translating the Arabic words *al-juz' al-muqaddam* and *al-juz' al-mu'akhkhar*) to designate respectively the forward and rear parts of the brain. The image of a ship immediately imposed the dominating character of the brain in the organization of the body. The work of ʿAlī ibn al-ʿAbbās forcefully introduced into medieval medical doctrine the theory of internal senses, intermediate between the intellectual powers of the soul and the five external senses. The *Isagoge*, the *Viaticum* and the *De oculis* of the Constantinian corpus put forward a similar exposition, insisting on the cerebral location of mental faculties and on the transmitter role played by the 'spirits' or *pneumata*, which are themselves subject to variations of both physical and emotional equilibrium. The introduction of this explanatory system caused a stir amongst twelfth-century theologians, who recognized the danger of an identification between spirits and the soul. A contemporary of William of Conches, William of Saint-Thierry, also a reader of the *Pantegni*, made a clarification of this point in his *De natura corporis et anime*: 'the various virtues, whether natural, vital or animal, are not the soul, but the instruments of the soul'. It is in this context that one should place John of Seville's translation of a treatise by Qusṭā ibn Lūqā tackling the problem of the difference between the spirit and the soul. Having taken these precautions, all the medical authors understood the stakes of Arabic theory concerning the internal senses which allowed them to make the link between psychology and physiology. With the passage of time, modifications to the number of ventricles and to the appellation of faculties were contributed by other Arabic works, such as the *De anima* and the *Canon* of Avicenna: they helped to refine the explicatory process which accounted, in the two directions, for the passage between mental states, normal and pathological, and physical states. One of the results of this representation can be found in the *De parte operativa* (Lyon 1504) of Arnald of Villanova (d. 1311) which gives in great detail a synthesis between Greco-Arabic nosology and the psycho-physiology resulting from the theory of internal senses.

To return to William of Conches, it is clear that the main information which he retained from the *Pantegni* concerned the theory of elements, which was more related to his philosophical purpose. It is impossible to enter here into the details of this utilization which is more relevant in the context of a deep discussion particularly related to the history of physics. It suffices to recall that the long passage which ʿAlī ibn al-ʿAbbās dedicates to the definition of the elements allows the Chartrian author to integrate the function of the human body at the heart of a cosmology. The same type of process characterized the Salernitan commentators of the twelfth century, who had a completely different aim: to relate medicine to the fundamentals of natural philosophy and thus to give it foundations conforming to the status of a 'science'.

According to the *Pantegni*, the four humours which constitute the human body (blood, phlegm, bile, melancholy) are 'called the daughters of the elements, since they are similar to these, as each humour is made up from their qualities' (*Theorica* I, 5). The humours in their turn form the solid constituents of the body. As a result, every part of the body, each process, normal or pathological, as well as all ingested ingredients, whether foodstuff or medicine, are subjected to the interaction of the primary qualities (heat, cold, dryness, humidity), which thus creates their *complexio* or temperament. The clear expose of this theory as found in the *Isagoge* and the *Pantegni* had a marked influence on the direction of Salernitan teaching. In the twelfth century a series of commentaries on the *Isagoge*, attributed to masters Bartholomeu, Petrus Musandinus and Maurus, discussed at length the problem of the mixing of qualities at the origin of temperament. They employed the terminology fixed for centuries by Constantine in the *Pantegni*: 'We refer to as temperament (*complexio*) that which is created by the mixing (*commixtio*) of elements' (*Theorica* I, 6). This definition is a more or less faithful translation of the *Kāmil* of ʿAlī ibn al-ʿAbbās: 'These qualities are called temperament (*mizāj*), this deriving from the mixing (*imtizāj*) of elements'. The Latin West was thus in possession of a clear definition and a unique denomination for a notion which had only become evident in previously available works under different names (the Hellenism *crasis*, *natura*, *qualitas*, *temperantia* or *temperies*). The problem of the mixing of qualities as the base of temperaments occupied a central position amongst the Salernitan commentators of the *Isagoge*. They came to use the recent Greco-Latin translation of Aristotle's *De generatione et corruptione* to try and understand more precisely the idea of 'mixing'. Thus it was scarcely by chance that Burgundio of Pisa, known for his links with Bartholomeu of Salerno, set himself the task of translating Galen's *De complexionibus*, a major source of ʿAlī ibn al-ʿAbbās on this problem. At the end of the twelfth century, Urso, the last famous master of Salerno, dedicated various works (*De commixtionibus*, *De effectibus qualitatum*) and long passages in his *Aphorismi* to the problem of the mixing of elements and the combination of properties within the body. At the core of the philosophically centred debates, the theory of the interaction of properties found an application in pharmacology. Another Constantinian translation, the *De gradibus* inspired by Ibn al-Jazzār, gave a clear definition of Galen's notion of degree: 'We say that the Ancients divided the temperament of a medicine into four parts and called these degrees. In effect they said that every medicine is either of the first degree, the second degree, the third degree or the fourth degree.' This definition introduced the listing of a series of simples which were affected by the degrees, giving a more precise level of the intensity of their dominating quality (heat, cold, dryness, humidity). In the middle of the twelfth century the facts provided by the *De gradibus* were integrated in the *Circa instans* by Platearius (Wölfel edition) which formed one of the most well-used sources of medieval pharmacopoeia. At the same time the theory of degrees became the object of discussions in the Salernitian environment at a time when the fundamental Galenic text on this subject, the *De simplici medicina*, was not, it would appear, as yet well known. In his *De gradibus* Urso tried to establish a method for determining the properties of the primary disposition of a substance and of a subject, paying particular attention to sensory apprehension.

By the clear definitions which it proposed, the Constantinian corpus gave a decisive impetus to the establishment of a medical science founded on a physiology capable of giving an account of the phenomena in their entirety. The *Isagoge* and the *Pantegni* also influenced the structure of medical teaching. These two works were based on a two-way division of medicine into theory and practice; their plan reflected this two-way division. The subdivision of science into theory and practice was not a new idea – it was mentioned in Aristotle (*Topics* VI, 1, *Metaphysics* II, 1) and had been developed by Macrobius and Boethius. As emphasized by Guy Beaujouan, the novelty, in the twelfth century, was to apply this distinction to specific disciplines, whilst earlier it had only been applied to philosophy as a whole. In this respect medicine was an exemplary case; the two-way division of medical science proposed in the *Isagoge* and the *Pantegni* was accepted even more readily since it had already been expressed in the Ravennate commentaries, of Alexandrian origin. The *Pantegni* offered a definition of the two subdivisions of medicine: 'theory is the perfect knowledge of items grasped by the intellect alone, subject to the memory of how things perform; practice consists of proving the theory, subject to the view of the senses and through manual operation, following the understanding of a pre-existing theory.' Through its very ambiguity, this definition encouraged numerous questions on the links of dependence before uniting theory and practice. In his commentary on the *Isagoge*, as it was transcribed in a Parisian manuscript (Bibl. nat., lat. 18499), Maurus of Salerno (d. 1214) expressed several possible differing points of view, but kept to the opinion that 'practice is a demonstrative science subject to theory'. He added, making reference to one of his predecessors, the archbishop Romuald Salernitanus, that one cannot be qualified as a 'practitioner' if one's acts are not dictated by an understanding of theory. Although this subjection of practice to theory, recognized by the majority of medieval authors, helped medicine to emerge from the framework of the 'mechanical arts', it often formed an obstacle to the introduction of experiment. Since practice was not considered as know-how but rather as 'a demonstrative science of theory', its teaching at university scarcely differed from the teaching of theory. In the thirteenth century, the West saw a reinforcement of this tendency, with the adoption of an Avicennian definition: 'When we say that one part of medicine is theory and the other part practice, it should not be considered that we mean that one part consists in knowledge and the other in action. ... One should realize that each subdivision is a science in itself, but that one is biased towards a knowledge of principles and the other towards the quality of operating skills.' The *Pantegni* was not content to provide a definition; it proposed to partition the subjects treated into theory and practice. University education was modelled to a large extent on this partitioning; the Bolognese statutes of 1405, which ratified earlier usages, predicted that every master should conduct scholarly discussion first in theory, then in practice. This partitioning was probably used at Salerno. The author of an *Anatomy*, which Karl Sudhoff has identified as Urso, presents his master Matthaeus Platearius as 'the precious gem of the Salernitan physicians in theory and practice'. The prologue to *Antidotarium Nicholai*, written without doubt around 1200, also reveals the importance of the definition disseminated by the *Pantegni*: 'I, Nicolas, at the request of certain individuals wishing to learn about the practice of medicine, in order to teach them in good order the art of producing and prescribing, and to give them a precise doctrine, ... I will put down in writing etc.'

Transmitted in a particularly fertile environment, the first works translated from Arabic gave a decisive direction to the teaching of medicine in the West. When one examines in detail the actual content of the teaching at Salerno, the acquisitions from Arabic texts are based on a Greco-Latin legacy. The vocabulary is often the only guide in determining the dominant influences. Thus Constantine the African introduced a number of new terms in anatomy: *mery* (*marī'*, for the oesophagus), *nucha* (*nukhā'a*, for the spinal cord), *siphac* (*ṣifāq*, for the peritoneum), *zirbus* (*tharb*, for the coil of peritoneum); although these words have gradually disappeared since the Middle Ages, the expressions *pia mater* and *dura mater*, rendering the terms *al-umm al-raqīq* and *al-umm al-jāfī* respectively, have remained in anatomic vocabulary to this day. The *Anatomies* written at Salerno are supposed to be based on the dissection of pigs; their descriptions intertwine the teachings of the *Pantegni* with a Greco-Latin basis. The first dated work, *Anatomia Cophonis*, which, in its original state, did not seem to take the *Pantegni* into account, in a revised format introduced a section using Arabic terminology. The same is true of the pharmacopoeia: the *Antidotarium Nicolai* integrates Arabic knowledge, in particular concerning sugar and syrups, with earlier facts. These examples could be multiplied and a number of questions remain as to the origin of certain ideas and practices. The *Circa instans* of Platearius seems to provide evidence of an Arabic influence when it describes the distillation of medicinal waters, although the Byzantines also practised this process.

The first Arabic translations, after passing through the Salernitan filter, played their role anew during the birth of the universities. The *Isagoge* of Iohannitius, placed at the head of the Articella collection which contained also Hippocratic and Byzantine treatises and Galen's *Tegni*, was the subject of many commentaries; the works of Isaac Israeli were part of university programmes until the end of the Middle Ages. However, the *Pantegni* and the *Viaticum* saw their success decline to the benefit of other summaries of medical science, such as Avicenna's *Canon* and the *Liber ad Almansorem* of Rhazes.

## THE SECOND WAVE OF TRANSLATIONS: IN PURSUIT OF THE ORIGINAL WORKS OF GALEN

When Gerard of Cremona died in Toledo in 1187, a century after Constantine the African passed away, the Latin West began to establish the institution of the university. In the middle of the thirteenth century the three great medical faculties of Paris, Montpellier and Bologna gradually integrated the content of the Toledan translations into their teaching programmes. Together with the Constantinian corpus, until the end of the Middle Ages these texts would serve as a point of departure in the initiation of students and in the discussions of masters. Like his predecessor at Monte Cassino, Gerard of Cremona translated from Arabic both original texts and the treatises from Greek. The fundamental works of Avicenna and Rhazes and the surgical part of the *Taṣrīf* of Albucasis (al-Zahrāwī) were known at the same time as an important series of Galenic treatises. Although Galen's work on anatomy was as yet only imperfectly transmitted, because the *De usu partium* did not appear in its entirety until the fourteenth century with the Greco-Latin version by Nicholas of Reggio, in the areas of physiology, pathology and therapeutics the Western masters could confront the works of the Arabs with the very sources of Galenism, the *De interioribus*, the *De locis affectis*, the *De morbo et accidenti*, the *De ingenio sanitatis* (*Methodus medendi*), etc. The points in common, the disagreements and the enhancements were examined with the fine toothcomb of scholastic reasoning and, from this dialectic, several different currents of thought were born which revealed the weaknesses and divisions of the proposed systems.

The end of the Middle Ages was marked by the dominant position accorded to the *Canon* of Avicenna in medical teaching. Gerard of Cremona's translation – very literal and full of transliterated Arabic terms – played the role which had been previously served by the *Pantegni*; it served as the privileged source of information in every field and was even used by non-physicians: the encyclopedist Bartholomeu the English secured its popularization in his *De proprietate rerum*. The influence of the *Canon* of Avicenna thus extended beyond the Middle Ages, because certain universities still kept it in their programme until the eighteenth century: Padua until 1767; Bologna, after abandoning it in 1721, reintroduced it from 1737 to 1800. About sixty complete or partial editions of the Latin *Canon* came into being between 1500 and 1674 and revisions of the medieval translation were undertaken. However, the reception of the medical work of Avicenna did not immediately follow its translation, nor did it have the same characteristics everywhere. The university of Bologna adopted this text as a fundamental manual from the second half of the thirteenth century. The commentators of the *Canon* were mostly Italians: Taddeo Alderotti (d. 1295), Dino del Garbo (d. 1327), Gentile da Foligno (d. 1348), Ugo Benzi (d. 1439), etc. The rigorous and sophisticated blueprint, the importance placed on aetiology and the introduction within the subject of the four types of Aristotelian causes (i.e. material, efficient, formal and final) lent itself to a scholastic style of teaching, closely linked to philosophy. Petrus Hispanus, not only a doctor but also a logician, recognized those aspects which could be used to good account; his various commentaries bear witness to an extensive use of the *Canon*, and his arrival in Sienna in 1246 was not without effect on the style of teaching in Italy. In both Paris and Montpellier, the introduction of Avicenna seemed to be met with more reserve and the *Canon* only gradually became the dominant authority during the first half of the fourteenth century.

Even in the most reluctant milieu, the enhancements provided by the Toledan translations of Arabic works in the field of pathology were recognized immediately. At the beginning of the thirteenth century, Girardus Bituricensis, one of the Parisian circle, proclaimed in his commentary on *Viaticum* (Venice, 1505) that he wanted to write a new work relying on

Avicenna and Rhazes; according to him these two Arab physicians filled a deficiency with their long accounts of the causes, signs and treatments of illnesses. Disregarding chronology, Girardus put both authors into the same scheme and did not realize what he owed to one or to the other. However, it seems that the description of measles first reached the Latin West via the *Canon*, which took up Rhazes's explanations on this issue. Without doubt, Avicenna's definition, insisting on the weaker intensity of measles in comparison with smallpox, encouraged Gerard of Cremona to translate *al-ḥasba* as *morbillus* (the diminutive of *morbus*, illness). The importance given to this new presentation of pathology in France can be illustrated by a selection of annotated texts: from the second half of the thirteenth century, the Parisian master John of Saint-Amand annotated the beginning of book IV of the *Canon*, dealing with fevers; in the fourteenth century Gerard of Solo, in Montpellier, commented on the same volume, book IV, as well as book IX of the *Almansor* by Rhazes describing illnesses *a capite ad calcem*. Another scholar from Montpellier, John of Tournemire, wrote a *Clarificatorium super Nono Almansoris* several years later. The two Arab authors also served as the principal source of information during the epidemic of 1348 which confronted the Western physicians with a problem their predecessors had never encountered. The numerous treatises dealing with the plague written in the fourteenth and fifteenth centuries depended on the *Canon* and the *Almansor* for both description and prescription. Avicenna's account of the spread of the disease by the contamination of the air provided major support to the Western explanation; the treatises from Granada by al-Shaqūrī, Ibn Khātima and Ibn al-Khaṭīb do not seem to have been known by physicians from a Latin background.

In the first phase of its introduction, the *Canon* was considered to be a vessel for new ideas concerning therapeutic medicine. The notion of temperament had itself been substantially modified with respect to the account of the subject written by al-Majūsī. The accent was placed on the role of relativism, which was involved in the understanding of dominant qualities. In his definition of temperaments (I, 1,3,1), Avicenna insists that it is impossible to define a well-balanced temperament absolutely, since the latter varies between two extreme limits with a latitude (*latitudo* = *ʿarḍ*) which can be large. Each constituent of the human being can only be characterized in quality in relation to another. The introduction of the notion of a specific form limits even further the possibility of basing a therapeutic system solely on the interaction of primary qualities: the action of an ingested product, food or medicine, simple or compound, is also determined by a property which is only defined by its effect (I, 2,2,1,15). In addition, the primary constituents within the mixture, whose potential remains unchanged according to Aristotelian theory, can either continue to react with one another, or can separate and react individually within the blood (II, 1,1). These propositions, which left a large part to chance in pharmacological action, retained the attention of scholars inclined to give greater importance to the role of experience in the explanation of natural phenomena. On several occasions Robert Grosseteste referred to Avicenna's notion of specific form. In his commentary on Aristotle's *Physics*, written around 1225–30, he relied on the *Canon* and cited the pertinent example of the magnet which attracts iron to show that a medicine can act as the result of an inherent property and not of quality (Dales 1963: 130). The action of compound medicines similarly provides Roger Bacon with the opportunity to make a statement concerning reason and experience: 'In the fifth book of the *Canon*, Prince Aboaly says that every compound medicine acquires its characteristics through its simples and from its form as a whole. The characteristic acquired by the simples can only be realized by reasoning, whilst that acquired by the form as a whole can only be known by experience.' (*Antidotarium*, *Opera hactenus inedita*, IX, 103–4). Roger Bacon, following the line of the *Canon* in this matter, gives greater importance to the actions which can only be proved by experience. Following these positions of principle, the *Antidotarium* presents a system for adapting the posology of compound medicines. This endeavour is written in the context of the quantification of qualities met in medieval physics.

The pharmacology presented by Avicenna posed, in a strictly Galenic context, the problem of the real action of the primary qualities. In his commentary on the *Antidotarium Nicolai* analysed by Michael McVaugh, John of Saint-Amand constructs a system which, whilst recognizing the unpredictability of the active properties of a compound medicine, tentatively returns to the primary qualities. At the end of the 'fermentation' which the simples undergo, a new active constituent of the 'complete form' is born, but traces of each constituent remain in proportion to their original representation. As a general rule, one remarks that John of Saint-Amand retains in particular those parts of Avicenna's teaching concerned with therapeutics. Whilst the first two sections of his *Revocativum memorie* are a sort of anthology of Galenic treatises, the third section, which lists in alphabetical order the attributes of simple and compound medicines, owes a particular debt to the second and fifth books of the *Canon*.

One cannot recall medieval pharmacology and the reception of the *Canon* without mentioning Arnald of Villanova, one of the greatest intellectual figures of the Middle Ages. Although open to experience in part of his works and in practice, the Catalan physician opted for a rational systematization of pharmacology. In this endeavour he depended on another Toledan translation, the *De gradibus* of al-Kindī which Roger Bacon in his *De erroribus medicorum* judged to be 'extremely difficult and practically completely unknown to Latin physicians' (*Opera hactenus inedita*, IX, 166–7). Arnald of Villanova kept to the pure Galenic tradition of primary qualities and their partition into four degrees of intensity within the temperaments. In the *Aphorismi de gradibus* (McVaugh 1975) written during the 1290s he established a mathematical pharmacology, using al-Kindī's work and the theory of 'primary quantities' formulated by Averroes; the law, by which the intensity of a quality (the degree) increases according to a mathematical progression whilst the link between the opposing forces from which it is derived follows a geometrical progression, is applied in detail to the dosage of compound medicines. The solution adopted is similar to that applied by the calculators of Oxford in the fourteenth century to the study of movement. This system, which reduces to a minimum the unpredictability in pharmacology, was followed for a time in Montpellier and was taken up once more in the fifteenth century by the physician of the Kings of Aragon, Antonio Ricart, in his treatise on posology; this author extended the theory of degrees to the variation of the humoral mass in his *Libellus de quantitatibus et proportionibus humorum* (Dureau-Lapeyssonie 1966). Despite these influences, the method constructed by Arnald of Villanova following al-Kindī was judged to be abstract and has had few followers.

Arnald of Villanova, an innovator in a tradition inspired by Galen, is a virulent detractor of Avicenna, even if he is occasionally inspired by him and although he personally translated the *De viribus cordis*. It was most probably in the context of controversy within the medical fraternity that he denounced on several occasions those who blindly followed the *Canon* of Avicenna. In the *De consideratione operis medicine* (Lyon 1504: 99) he declared that he had proved in his commentaries on the *De malitia complexionis diverse* and on the *De morbo et accidenti* that 'the solid truth of Galen was not understood by Avicenna, who by his abundant outpourings on the subject of medicine has made fools of the major proportion of Latin physicians'. In the same work, Arnald reproached the scholars who referred to the authority of Avicenna without understanding: 'They hold discussions under his authority, without recalling the proof, and it seems they are happy if they can see, read or show from their great pulpits the weight of the volume.' To understand Avicenna for Arnald of Villanova undoubtedly meant to pass his works through the filter of Galenism. The prologue to *De intentione medicorum* (Lyon 1504: 51) indicates the two guides which medieval medicine should follow, i.e. Galen of course, but also Rhazes: 'This little book on the purpose of physicians is based on the teachings of several authors, i.e. Galen and certain Arabs including Rhazes, a man of clear thought, prompt in his work, decisive in judgement and trustworthy in experiment. He has especially procured for us an introduction in his small book on the concord between philosophers and physicians; in this pamphlet, even if the purpose of the material affirmations does not appear plainly, at least the way in which to understand the affirmations is provided in illuminating fashion. The obscurities which often frighten you in Galen's books are clarified by the brilliant light of this work.' The wise Arab is thus considered as the best successor to Galen, whose intentions he knew how to comprehend. One can ask whether Arnald of Villanova, an Arabic speaker, was able to consult the *Kitāb al-Shukūk ʿalā Jālīnūs* of which there is no known Latin version. One of the criticisms that Rhazes addresses to Galen in this book concerns the action of the first qualities within an ingested substance, a subject which was particularly dear to Arnald of Villanova.

Even in Montpellier the resistance concerning Avicenne's *Canon* did not have much of a future. The 1309 curriculum, influenced by Arnald of Villanova, included an important number of Galenic treatises and left a choice between Avicenna and Rhazes; in 1340, the first book of the *Canon* became compulsory and parts of the third and fourth books became possible options. The name of Rhazes no longer appeared in the list of the programme's authors. The pedagogical possibilities of the *Canon* were fully exploited, at the same time as it appeared in the majority of universities as a recourse in the face of the affirmations of the *Colliget* of Averroes.

## THE TRANSLATIONS OF THE THIRTEENTH CENTURY: FROM PHILOSOPHY TO PRAGMATISM

The second half of the thirteenth century saw the introduction of the medical ideas of Ibn Rushd, the Averroes of the Latins, some fifty years after the shock presented to the West by the philosophy of Averroism. In 1284 Arnald of Villanova's nephew, Armengaudus Blasius, translated in Montpellier the commentary on the *Cantica* (*Urjūza fī al-ṭibb*) of Avicenna; in 1285, at the latest, the Jew Bonacosa, in Padua, translated into Latin the *Kitāb al-Kulliyyāt*, known under the title of the *Colliget*. This last work was the source of many controversies which allowed the Western physicians to make their doctrine more precise.

The major difficulty rested in the confrontation between Galenism and Aristotelianism. The *Colliget* reinforced the positions of Aristotle's *De animalibus*, known in the West before 1220 in the Arabo-Latin version by Michael Scot, then directly from the Greek via William of Moerbeke's translation in 1260. One of the points of this confrontation was the famous question of female semen and its role during reproduction. According to Aristotle, the man, through the intermediary of his sperm, gives form to the embryo, whilst the woman only contributes matter in the flow of menstrual blood. There is no place for an active female constituent: the sex of the infant and the transmission of dominant characteristics depend totally on the strength or weakness of the male sperm. According to Galen – whose theory first came to the West in the work of al-Majūsī – the woman emits a semen which actively intervenes in fertilization. The *Colliget* (II) gives its unconditional support to the explanation provided by the *De animalibus*, using new arguments. For example, the role of the ovaries, unknown to Aristotle, is compared with that of the male breasts – devoid of all function; Averroes went outside his own experience when he related an anecdote which gave rise to the scorn of the Galenist physicians: one of his neighbours became pregnant through the water of a bath into which a man had spilled his sperm. One could not reduce a woman to a more passive role. Although the Averroist position was adopted by theologians such as Gilles of Rome (d. 1316), it could not be completely accepted by the physicians. In 1310, Pietro d'Abano wrote his *Conciliator* (Mantoue 1472) destined to reconcile physicians and philosophers, i.e. Aristotle and Averroes on the one hand and Galen and Avicenna on the other. On the question of female semen, his compromise consisted of pronouncing that the ovaries only serve to produce 'a dampness which incites the desire to receive the virile semen in the most appropriate fashion' (*Diff.* XXVIII). Although the *Colliget* emphasized the inadequacy of the term sperm for the female substance, it did not succeed in imposing the Aristotelian interpretation on the medical fraternity. The theory of a double semen explained hereditary mechanisms more finely, at the same time serving to explain the different female discharges within which those of functional leucorrhoea were often confused with vaginal secretions. One had to wait until the sixteenth century for the role of the ovaries to be clearly appreciated by Gabriele Falloppio. Despite differences in detail, a sort of consensus was established among physicians towards the end of the Middle Ages, giving preference to the compromise of Avicenna's *Canon* (III, 20,1,3): the masculine sperm was more susceptible to providing the form, the feminine sperm was more suited to receiving it.

As a reinforcement of Aristotelian ideas, the *Colliget* also contributed to posing fundamental questions in a new guise. Thus, from the last years of the thirteenth century until the seventeenth, the different definitions of fever were divided around the divergent positions of Avicenna and Averroes. The Western physicians learnt from a reading of the *Canon* that 'fever is an extraordinary heat which, emanating from the heart and carried by the spirits and the blood, is diffused along the arteries and the veins throughout the whole body, attaining a heat sufficient to cause a loss of natural functions' (IV, 1,1,1). Two propositions of Averroes (*Colliget* III, 4) were generally retained: 'fever is a natural heat mixed with a certain degree of putrid heat' and 'it is a heat which seizes the whole body, injuring all the actions and the passions of the organs'. The Averroist thesis leads to an analysis in detail of the progression from a natural heat to a feverish heat. Despite numerous differences amongst medieval authors, the solution of the *Colliget* was examined without difficulty since, on this point, it could be compared with one of Galen's allusions: 'fever occurs by a conversion from an innate heat to a burning fire' (commentary on the *Aphorisms* of Hippocrates, I).

The *Colliget* played a provocative role again by restoring topicality to the definition of medicine as an art. The respective roles of theory and practice, as they appeared in the *Pantegni* and the *Canon* of Avicenna for example, were challenged. According to Averroes (*Colliget* 1,1), medicine is an 'art of operating'. It is founded on a speculative part, which is natural science, and a practical part, which encompasses 'the experimental art of medicines' and 'the art of anatomy'. Practice acquired a sort of autonomy, because it was no longer simple deduction from theory but was nourished by experience and by personal know-how. Without always adopting a global definition of medicine as art, Western authors re-examined the ambiguous status of practice. In the *Conciliator* (III, 4), Pietro d'Abano gathered together the definitions given by the Arabs and tried to find a middle course. He identified a distinction within practice: one part touching universals could be the subject of generalization and constitute a science; the other part consisting of treating such and such a particular case relied on experience and thus constituted an art (or a technique).

The discussion of the definition of medicine provided by the *Colliget* found even more of an echo when, in the second half of the thirteenth century, attention was focused anew on how to explain the *particularia*, i.e. the infinity of circumstances met in daily practice. Taddeo Alderotti, perhaps influenced by the habits of the Bolognese lawyers, assured the success of genre of *Consilia*, example types of treatments applied in real or fictitious cases. At the same time, Arabic works, early or recent translations, were searched for precepts on the daily art and relations of pathological cases. In the 1250s, a scholar, almost certainly an Italian, called Isidore wrote a commentary on a text translated in the twelfth century and widely diffused, the *Aphorismi Iohannis Damasceni* (*Nawādir al-ṭibb* of Ibn Māsawayh). Amongst the twenty or so manuscripts which preserve this commentary, some also transcribe the *Colliget* of Averroes. Ibn Māsawayh does not fail to recall the rational and bookish foundations of medicine, offering a formula unflaggingly repeated in the Middle Ages: 'When Galen and Aristotle are in agreement on something, that is it; when they disagree, the right of the thing is very difficult for the mind to comprehend' (*Aph.* 8). Isidore's commentary gave preference to those parts, in the Arabic text, which belong to the Hippocratic tradition, putting the emphasis on the know-how of the physician. Of course, the good practitioner should take notice of all the cases presented by the ancient authors so that his art should not be 'a dagger in the hands of a furious madman', but he must also prove himself to be astute and experienced in how to approach particular cases. These qualities come back to the Aristotelian notion of *prudentia*, the prerogative of the artisan.

The translations developed from the Arabic in the second half of the thirteenth century respond to the same desire to enlarge the field of information on specific problems posed by practice as much on a diagnostic level as on a therapeutic one. The Latin version of the *Sirr ṣināʿat al-ṭibb* of al-Rāzī (*De secretis in medicina*), whose third chapter is dedicated to the relation between cases encountered in practice, probably influenced Arnald of Villanova when he wrote his *Experimenta* (McVaugh 1975). In 1282, the Jewish translator of Sicily, Faraj ben Sālim, opened to the West, under the title *Continens*, the enormous *al-Ḥāwī*, assembling in a disorganized fashion clinical observations, interpretations and prescriptions of the Ancients as well as those of Rhazes himself. A year earlier the *Theisir* of Avenzoar (Ibn Zuhr), in which the supposed master of Averroes peppered his discourse with references to his personal experience, had been translated from Arabic. It is incontestable that the choice to translate these works rather than others responded to a resurgence of attention to the facts of practical experience. In the same way, physicians not only set down in writing 'counsels' relating, according to the expression used in the fifteenth century by Ugo Benzi, 'remedies proved in numerous cases' (Lockwood 1951: 289) but also introduced into their most scholastic works the accounts from their practices. This intrusion of reality became amplified in the medical works at the end of the Middle Ages, which also incorporated anatomical observations made during the course of dissections.

In the last two centuries of the Middle Ages, the Arabic influence was no longer evident in the translation of new texts; successive contributions were intermingled and each author drew from Greco-Latin and Arabo-Latin depths, whichever could best inform him and support the thesis he was defending. In the fifteenth century, a Parisian commentator on Avicenna's *Canon* Jacques Despars (d. 1458), unveiled his method of working. To understand and enrich Avicenna's text, he affects not to cite the Latin authors and declares his reliance on 'the illustrious Greeks, Hippocrates, Aristotle, Galen and Alexander [of Tralles] as well as the most famous Arabs, Avenzoar, Rhazes, Serapio, Mesue and Averroes' (Lyon 1498). The qualifications which he gives to several Arab authors tend to characterize their contribution to medieval science. Rhazes is 'the supreme experimenter', 'the greatest and most experienced physician after Hippocrates and Galen'. Mesue, who in this case corresponds to pseudo-Ibn Māsawayh, author of works on pharmacopoeia, is referred to by Jacques Despars as 'our expert', 'our evangelist', 'the most knowledgeable of all for describing medicines clearly'. As for 'good Averroes', qualified with the epithet 'the club', he is supposed to have corrupted all physicians.

Throughout the successive waves of translations, the medical vocabulary became more and more precise, but it also gained numerous words from Greek and Arabic, some of which had two uses. In his *Synonyma* or *Clavis sanationis* (Milan 1473), Simon of Genoa created, at the end of the thirteenth century, a sort of dictionary, principally dedicated to medical material. From the definitions in these *Synonyma*, one can measure how the ignorance of a translator or the error of a copyist can give rise to conceptual nuances which become more marked with the passage of time. The descent from the Greek *phrenitis* is particularly enlightening. Becoming in Arabic *farānītis*, then *qarānītis*, the word passed into Latin in the form *karabitus* attributed to it by Gerard of Cremona. According to Simon of Genoa *karabitus* designates 'a hot swelling of the brain's membrane', whilst *frenesis*, introduced into Latin from Antiquity from the same word *phrenitis*, applies to raging madness, a principal symptom of the illness. Although coming from the same concept, *frenesis* refers to the ancient description of mental affliction of which the seat could be the diaphragm, *karabitus* to Avicenna's interpretation fixing the origin of the 'madness' in the brain. When the Renaissance humanists wanted to eliminate Arabic terms from medical vocabulary, they also swept the table of nuances which reflect the historic evolution of concepts.

Multiform and often contradictory, the Arabic contribution to medieval Latin medicine is situated, for the most part, in the context of a confrontation with the teachings of Galen. In so far as the Western authors knew the Greek author better, they were better armed to judge the originality of the Arab physicians. After the Middle Ages the influence of a scholar from Damascus in the thirteenth century played a role in questioning an important element of Galenism. Common points can be raised concerning the description of the pulmonary circulation of the blood – the so-called little circulation – between the commentary of Ibn al-Nafīs on the *Canon* of Avicenna and the observations made in the middle of the sixteenth century by Michel Servet, Realdo Colombo and Giovanni de Valverde. Although this influence would seem to be incontestible, its path of action remains unknown. Whilst evidence is offered that an Arabic manuscript of the work of Ibn al-Nafīs was in the possession of a Venetian family in about 1700, the part of the Latin translation by Andrea Alpago (d. 1522) of the commentary on Avicenna's *Canon* which was published in Venice in 1547 is not concerned with anatomy. One must thus assume either that manuscripts were in circulation which are now lost or, more probably, that transmission was oral. In effect it seems difficult to imagine that Andrea Alpago, who, in Damascus, followed the teachings of Ibn al-Makkī and who undertook to translate the work by Ibn al-Nafīs, should have no knowledge of this new theory of pulmonary circulation. He himself and, after his death, his nephew Paolo, editor of his works, would have been able to communicate in the medical milieu of Padua and Venice. A proof of this knowledge is provided for us by a digression on the pulse which Andrea placed within the translated part of the commentary of Ibn al-Nafīs. There he presents several remarks on Galen's theory in relation to the movement of the heart and the arterial system, as well as elements of the critique of Ibn al-Nafīs.

*Table 28.1* Table of the major translations of Arabic medical works into Latin

This table does not claim to be an exhaustive listing of all translations of Arabic medical works into Latin, but one of those which had the greatest impact. For the Arabic originals, reference is made to the works of Fuat Sezgin (S) and Manfred Ullmann (U). For the Latin versions, reference is to a modern edition or to one of the earliest Renaissance editions or to Lynn Thorndike's and Pearl Kibre's catalogue (TK).

| Translator | Arabic original | Translation |
|---|---|---|
| CONSTANTINE THE AFRICAN ?<br>Anonymous. Southern Italy. 11th century. | ḤUNAYN IBN ISḤĀQ and ḤUBAYSH<br>*Masā'il fī al-ṭibb* (S, pp. 249–50) | IOHANNITIUS<br>*Isagoge ad Tegni Galeni* (Ed. G. Maurach, 1978) |
| CONSTANTINE THE AFRICAN ?<br>Southern Italy. 2nd half of 11th century | ISḤĀQ IBN SULAYMĀN AL-ISRĀ'ĪLĪ<br>*Kitāb al-Ḥummayāt* (S, p. 296)<br>*Kitāb al-Aghdhiya* (S, p. 296)<br><br>*Kitāb al-Bawl* (S, pp. 296–97) | ISAAC ISRAELI<br>*Liber de febribus* (Ed. Lyons, 1515)<br>*Liber de dietis universalibus et particularibus* (Ed. Lyons, 1515)<br>*Liber de urinis* (Ed. Lyons, 1515 and J. Peine, 1919) |
| | ḤUNAYN IBN ISḤĀQ<br>*Tarkīb al-ʿayn* (S, p. 251) | CONSTANTINUS AFRICANUS<br>*Liber de oculis* (Ed. Lyons, 1515 and P. Pansier, vol. 7, 1909–33) |
| | ʿALĪ IBN AL-ʿABBĀS AL-MAJŪSĪ<br>*Kāmil al-ṣināʿa al-ṭibbīya* (S, p. 321) | CONSTANTINUS AFRICANUS<br>*Pantegni* (Ed. Lyons, 1515) |
| | ISḤĀQ IBN ʿIMRĀN<br>*al-Maqāla fī al-Mālīkhūliyā* (S, p. 266) | CONSTANTINUS AFRICANUS, RUFUS<br>*De melancolia* (Ed. K. Garbers, 1977) |
| | IBN AL-JAZZĀR<br>*Zād al-musāfir wa-qūt al-ḥāḍir* (S, p. 305)<br>*Kitāb Iʿtimād al-adwiya al-mufrada* (S, p. 304) | CONSTANTINUS AFRICANUS<br>*Viaticum* (Ed. Lyons, 1515)<br>*De gradibus* (Ed. Lyons, 1515) |
| | IBN AL-JAZZĀR (?)<br>*Kitāb al-Miʿda* (S, p. 306)<br>*Kitāb al-Jūdham* (S, p. 307)<br>*Zād al-musāfir*, VI (S, pp. 305–306)<br>[Treatise for a sultan on forgetting] (S, p. 306) | CONSTANTINUS AFRICANUS<br>*Liber de stomacho* (Ed. Lyons, 1515)<br>*De elephantiasi* (Ed. Lyons, 1515)<br>*De coitu* (Ed. E. Montero Cartelle, 1983)<br>*De oblivione* (Ed. Lyons, 1515) |

(*Continued*)

*Table 28.1 (Continued)*

| Translator | Arabic original | Translation |
|---|---|---|
| Anonymous, Italy, 2nd half of 11th–1st half of 12th century | YŪḤANNĀ IBN MĀSAWAYH<br>*Nawādir al-ṭibb* (S, p. 233) | IOHANNIS DAMASCENI<br>*Aphorismi* (Ed. D. Jacquart and G. Troupeau, 1980) |
| STEPHEN OF PISA<br>Antioch, 1st half of 12th century | ALĪ IBN AL-ʿABBĀS AL-MAJŪSĪ<br>*Kāmil al-ṣināʿa al-ṭibbīya* (S, p. 321) | HALY ABBAS<br>*Regalis dispositio* (Ed. Lyons, 1923) |
| JOHN OF SEVILLE<br>Spain. 1st half of 12th century | QUSṬĀ IBN LŪQĀ<br>*Risāla fī al-Faṣl bayna al-rūḥ wa-al-nafs* (U, p. 128) | COSTA BEN LUCA, CONSTABULUS<br>*De differentia spiritus et anime* (Ed. C. S. Barach, 1878) |
| 12th century? Translation falsely attributed to Arnald of Villanova | ?<br>(U, p. 127) | *De physicis ligaturis* (Ed. Lyons, 1504) |
| GERARD OF CREMONA<br>Toledo, 2nd half of 12th century | ʿALĪ IBN RIDWĀN<br>[comm. Galen]: *al-Ṣināʿa al-ṣaghīra* (S, p. 81) | HALY RODOHAN<br>*Expositio ad Tegni Galeni* (Ed. Venice, 1496) |
| | YŪḤANNA IBN SARĀBIYŪN<br>*al-Kunnāsh al-ṣaghīr* (S, p. 241) | SERAPIO<br>*Practica, Breviarium medicine* (Ed. Venice, 1479) |
| | AL-KINDĪ<br>*Risāla fī Maʿrifat quwa al-adwiya al-murakkaba* (S, p. 245) | IACOB ALKINDI<br>*De gradibus* (Ed. M. R. McVaugh, 1975) |
| | AL-RĀZĪ<br>*al-Kitāb al-Manṣūrī fī al-ṭibb* (S, p. 281)<br>*Taqsīm al-ʿilal* (S, p. 284)<br>*Kitāb al-Mudkhal ilā al-ṭibb* (S, p. 284)<br>*Awjāʿ al-mafāṣil* (S, p. 288)<br>*Kitāb al-Aqrābādhīn* (S, p. 283)<br>? | RASIS<br>*Liber ad Almansorem* (Ed. Milan, 1481)<br>*Liber divisionum* (Ed. Milan, 1481)<br>*Introductio in medicinam* (Ed. Venice, 1497)<br>*De egritudinibus iuncturarum* (Ed. Milan, 1481)<br>*Antidotarium* (Ed. Venice, 1497)<br>*Practica puerorum* (Ed. Milan, 1481) |
| | ISḤĀQ IBN SULAYMĀN AL-ISRĀʾĪLĪ<br>*Kitāb al-Ḥudūd wa al-rusūm* (U, p. 138)<br>*Kitāb al-Usṭuqussāt* (U, p. 138) | ISAAC ISRAELI<br>*De elementis* (Ed. Lyons, 1515)<br>*De definitionibus* (Ed. J. T. Muckle, 1937–38) |

| | | |
|---|---|---|
| | AL-ZAHRĀWĪ<br>*al-Taṣrīf li-man ʿajiza ʿan al-taṣnīf*, 30 (S, p. 324) | ALBUCASIS<br>*Chirurgia* (Ed. Venice, 1497) |
| | IBN SĪNĀ<br>*Kitāb al-Qānūn* (U, pp. 152–54) | AVICENNA<br>*Liber Canonis* (Ed. Milan, 1472) |
| | IBN WĀFID<br>*Kitāb al-Adwiya al-mufrada* (U, p. 273) | ABENGUEFIT<br>*Liber de medicamentis simplicibus* (Ed. Strasbourg, 1531) |
| MARK OF TOLEDO<br>Toledo 2nd half of 12th century | ḤUNAYN IBN ISḤĀQ<br>*Masā'il fī al-ṭibb* (S, pp. 249–50) | IOHANNITIUS<br>*Liber isagogarum* (ms. Vatican, Pal. lat. 1098 ?) |
| Anonymous, 12th or 13th century | PSEUDO-YUḤANNĀ IBN MĀSAWAYH<br>? | MESUE<br>*De consolatione medicinarum simplicium, Antidotarium, Grabadin* (Ed. Venice, 1471) |
| GILES OF SANTAREM<br>Portugal, 2nd half of 13th century | AL-RĀZĪ<br>*Maqāla fī Sirr ṣinā'at al-ṭibb* (S, p. 286) | RASIS<br>*De secretis medicine, Aphorismi Rasis* (Ed. Milan, 1481) |
| | YUḤANNĀ IBN MĀSAWAYH<br>*Nawādir al-ṭibb* (S, p. 233) | *De secretis medicine*, VI (Ed. D. Jacquart and G. Troupeau, 1980) |
| RUFIN OF ALEXANDRIA<br>Murcia, 2nd half of 13th century | ḤUNAYN IBN ISḤĀQ<br>*Masā'il fī al-ṭibb* (S, pp. 249-50) | HUNEN<br>*Liber questionum medicinalium discentium in medicina* (TK, 716) |
| DOMINICUS MARROCHINUS<br>Murcia, 2nd half of 13th century | ʿALĪ IBN ʿĪSĀ<br>*Kitāb Tadhkirat al-kaḥḥālīn* (U, p. 208) | JESU HALY<br>*Epistola de cognitione infirmitatum oculorum* (Ed. P. Pansier, vol. 3, 1903) |
| BONACOSA<br>Padua, 2nd half of 13th century (1255? 1285?) | IBN RUSHD<br>*Kitāb al-Kulliyyāt* (U, p. 166) | AVERROES<br>*Colliget* (Ed. Venice, 1490) |
| ARNALD OF VILLANOVA<br>Montpellier, 2nd half of 13th century | IBN SĪNĀ<br>*Maqāla fī Aḥkām al-adwiya al-qalbīya* (U, p. 155) | AVICENNA<br>*De viribus cordis* (Ed. Venice, 1489) |

(*Continued*)

*Table 28.1 (Continued)*

| Translator | Arabic original | Translation |
|---|---|---|
| | ABŪ AL-ṢALT<br>*Kitāb al-Adwiya al-mufrada* (U, p. 276) | ALBUZALI<br>*De medicinis simplicibus* (TK, 801) |
| PROFATIUS and<br>BERNARDUS HONOFREDI<br>Montpellier, 2nd half of 13th century | IBN ZUHR<br>*Kitāb al-aghdhiya* (U, p. 201) | AVENZOAR<br>*De regimine sanitatis* (TK, 187) |
| ARMENGAUDUS BLASIUS<br>Montpellier, 2nd half of 13th century | IBN SĪNĀ – IBN RUSHD<br>*al-Urjūza fī al-ṭibb*, comm. (U, pp. 155–167) | AVICENNA – AVERROES<br>*Cantica cum commento* (Ed. H. Jahier and A. Noureddine, 1956. Venice, 1523) |
| JOHN OF CAPUA ? and JACOB<br>Padua, 2nd half of 13th century | IBN ZUHR<br>*Kitāb al-Taysīr* (U, p. 163) | AVENZOAR<br>*Theisir*, trans. from Hebrew (Ed. Venice, 1490) |
| FARAJ BEN SALEM<br>Sicily, 2nd half of 13th century | AL-RĀZĪ<br>*al-Ḥāwī* (S, pp. 278–80) | RASIS<br>*Continens* (Ed. Brescia, 1486) |
| Sicily, 2nd half of 13th century | IBN BUṬLĀN<br>*Kitāb Taqwīm al-ṣiḥḥa* (U, p. 157) | IBN BOTLAN, ELLUCHASEM ELIMITHAR<br>*Tacuinum sanitatis* (Ed. Strasbourg, 1531) |
| SIMON OF GENOA<br>ABRAHAM TORTUENSIS<br>Italy, 2nd half of 13th century | PSEUDO-IBN SARĀBIYŪN<br>?<br>(U, pp. 283–84) | SERAPIO<br>*Liber de simplicibus medicinis* (Ed. Venice, 1479) |
| | AL-ZAHRĀWĪ<br>*al-Taṣrīf li-man ʿajiza ʿan al-taṣnīf*, 28 (S, p. 324) | ALBUCASIS<br>*Liber Servitoris* (Ed. Venice, 1471, repr. in M. Engeser) |
| ? | ?<br>(U, p. 211, 212, 348) | ALCOATI<br>*Congregatio sive liber de oculis* (Ed. P. Pansier, Vol. 2, 1903) |
| JOHN JACOBI<br>Lerida ?, 2nd half of 14th century | | *Liber de la figura del uyl*, Catalan version (Eds L. Deztany and J. M. Simon de Guilleuma, 1933) |

# 29

# *The scientific institutions in the medieval Near East*

FRANÇOISE MICHEAU

The history of the scientific institutions in the medieval Near East, libraries of rich collections, hospitals where numerous and competent personnel were employed, observatories which enabled the realization of remarkable astronomical works, is closely linked to the history of the sovereigns who founded them and the scholars who enlivened them. For intellectual life depends, directly or indirectly, on the goodwill of the caliph; it is from him that it receives the necessary moral and financial support. It would not have had the foundation of a library, the construction of a hospital, the project of translation, without the financing by a silent partner, a vizier, a notable power in the court, a military chief, who only acts if he has the necessary resources and if he finds approval and encouragement in the caliph, unless he is trying to compete with him. In a sense, the only scientific institution in the medieval Arabic world was patronage.

Far from being continuous and divided evenly in time and space, the activity of the men of science and the institutions that were theirs is concentrated around several poles: Baghdad under the Abbasid caliphs Hārūn al-Rashīd and al-Ma'mūn, the great Buwayhid metropolises of the fourth/tenth century – Rayy, Isfahan, Shīrāz, Baghdad – Egypt in the Fatimid era, Ayyubid Syria, etc. But one must be careful there: the scientific movement does not amount to the sudden infatuation of a few caliphs and viziers with more or less obscure motives; it is inscribed in a veritable political plan among sovereigns anxious to establish the prestige of their regime, to guarantee the services of scholars, to favour certain movements of ideas. Al-Ma'mūn, who was Caliph from 198/813 to 218/833, is a remarkable example.

## THE *BAYT AL-ḤIKMA* OF BAGHDAD: A LIBRARY

In its time, Baghdad possessed a library where astronomers, mathematicians, scholars and translators worked and met together. It was known by the name *Bayt al-ḥikma*. Modern authors take pleasure in encountering there the foundation of an enlightened prince, friend of the arts and sciences, and faced with a lack of precise information have a tendency to make of the *Bayt al-ḥikma* a sort of academy bringing together all intellectual activity concerned with secular disciplines. A thorough study led by Marie-Geneviève Balty-Guesdon allows us today to have a more exact idea about the role and function of this institution.[1]

Some libraries existed in the Umayyad and Abbasid palaces; certain sovereigns reputed to be interested in the sciences and translations, such as Khālid b. Yazīd or al-Manṣūr, have certainly enriched the caliphal library with works reflecting their tastes. The term *Bayt al-ḥikma*, or its equivalent *Khizānat al-ḥikma*, appeared in the reign of Hārūn al-Rashīd. Caliph al-Ma'mūn, if he was not the founder of this institution, gave a very strong impulse to the scientific activity which is linked with it. The *Bayt al-ḥikma*, library for the use of the prince, became then a library open to the élite scholar, an expression of a broad intellectual policy.

All the sources show the *Bayt al-ḥikma* as a library collecting together mostly works of philosophy and science; the term *ḥikma* refers in all Arabo-Muslim culture not only to wisdom and speculative and philosophical thought properly so called, but also to all forms of knowledge inherited from Antiquity that are the sciences described as 'rational sciences' or 'sciences of the Ancients'.

The *Bayt al-ḥikma* is enriched with manuscripts from the Byzantine empire. An author from the fifth/eleventh century, Ṣā'id al-Andalusī, reports that Caliph al-Ma'mūn entered into relations with the emperors of Constantinople who sent him 'works by Plato, Aristotle, Hippocrates, Galen, Euclid, Ptolemy and others still'.[2] But these external acquisitions, recorded by the chroniclers who like to indicate the exceptional, weigh little next to the collections available in the Abbasid empire: in the towns of Alexandria, Antioch, Edessa, Ḥarrān, Nisibis a number of monasteries maintained an intellectual life; Greek philosophical and scientific works were preserved, commented upon, compiled, translated into Syriac there. As in many other areas, the Arab conquerors respected the previous situation. Far from bringing it to an end, they pursued and increased this movement to translate and integrate the knowledge of Antiquity. Must one, once again, denounce the myth about the burning of the library of Alexandria? Also, when a scholar from Baghdad wished to translate a Greek work, he went to search for a manuscript not in the faraway Byzantine territories but in these ancient sources of Hellenistic culture, and his new version would come to enrich the collections of scientific works of the *Bayt al-ḥikma* or other libraries.

## THE *BAYT AL-ḤIKMA* OF BAGHDAD: A CENTRE OF TRANSLATIONS?

Many scholars are cited for having translated, in the time of al-Ma'mūn, works of astronomy, geometry, medicine, philosophy; but it is difficult to define the exact role of the *Bayt al-ḥikma* in their enterprise. Although it is true that certain among them were employed in this establishment, the majority answered to the pointed demand of the Caliph, of an important person in the court, of a colleague. Caliph al-Ma'mūn played a decisive role, but other silent partners dedicated important sums to the translations. This would simplify or extend the link to the *Bayt al-ḥikma* of all men working on translations. In his thesis on Arabic libraries, Youssef Eche supposed a rigorous organization of translations in the *Bayt al-ḥikma*: its secretary would have been in charge of choosing the works to be translated, of sharing them out among the scholars, of controlling their work, of correcting it if necessary, and finally of integrating these new texts into the collections of the *Bayt al-ḥikma* after having made the necessary copies.[3] But nothing leads one to think that there was such planning. The principal role that the *Bayt al-ḥikma* played was to provide manuscripts and to put the translated books at the disposal of the scholars.

Like every library, the *Bayt al-ḥikma* was a place where one came to copy works. One is familiar with a certain ʿAllān b. Ḥasan al-Shuʿūbī, a bookseller with a shop in Baghdad and renowned copyist: he worked in the *Bayt al-ḥikma* for Hārūn al-Rashīd, al-Ma'mūn and the Barmecides, and without doubt he also made some copies there to sell in his shop. Other activities had the *Bayt al-ḥikma* as their setting. Reunions of scholars took place there but, paradoxically, those with which we are familiar concern the religious sciences. It is possible that the *Bayt al-ḥikma* played a non-negligible role, but difficult to evaluate, in the reconciliation of philosophy and the religious sciences, contributing thus to the elaboration of mu'tazilism before its adoption as official doctrine. Through this philosophical and political stake, the *Bayt al-ḥikma* is linked, more than is generally said, to the evolution of Islam in its opening up to rationality. The absence of physicians among the scholars who frequented this library, when medicine, largely dominated by Christians, had the use of its own places of transmission, could suggest this. But this is not the only indicator. At the head of this institution there was a *ṣāḥib*, and several of those who exercised this function of directing are known to us: in the time of al-Ma'mūn they were recruited not amongst the men of science, the philosophers, the translators, but in the circle of the *kuttāb* of the administration.

Plenty of questions remain: where was the *Bayt al-ḥikma* situated? How did it function? When and why did it disappear? Perhaps divided into several sections at the time of transfer from the capital to Samarra in 221/836, perhaps abandoned when Caliph al-Mutawakkil (232/847–247/861) condemned muʿtazilism, this library lost its important role after the reign of al-Ma'mūn. Scientific activity did not stop in the same way. On the contrary, Baghdad became familiar then with a blossoming of men of science, thanks to the support of the Abbasid Caliphs and their viziers and then, after 334/945, of great Buwayhid emirs.[4] The place that al-Qifṭī gives to this period in his dictionary of scholars illustrates this affirmation. This erudite Aleppin, who died in 646/1248, gives the biographies of 415 men of science, of whom 297 lived between the appearance of Islam and his time; 158 of them, i.e. more than half, are situated in the second/ninth and third/tenth centuries, 113 in Iraq.[5] Baghdad was then the pole of attraction which pulled all the intellectual forces of the Muslim world. Among the scholars of this period, al-Qifṭī mentions thirty-seven Christians, eleven Sabeans and eight Jews, and confirms the role of non-Muslims in Arabic scientific development. This intellectually brilliant life, largely interconfessional, was organized around multiple centres: the court of the sovereign, the shops of booksellers, the mosques, the Christian schools, the houses of important people and, to continue our presentation of scientific institutions, the libraries and hospitals.

## PRIVATE AND PUBLIC LIBRARIES

There is no lack of Arab poets who have evoked the faithful companionship of books or of the well-read who have been great bibliophiles. Ibn Abī Uṣaybiʿa described, amongst others, the library of the physician Ibn al-Muṭrān, with a wealth of more than 3000 volumes; three copyists worked constantly in his service, and he himself calligraphed numerous books; on his death, in 578/1191, this exceptional collection was sold and ʿImrān, another bibliophile physician, was the lucky acquire.[6] Another private collection knew a very different fate: the wife of al-Mubashshir b. Fātik, jealous of the affection and interest that her scholar husband placed on his texts and his studies, avenged herself after his death by throwing all the books into a basin.[7] From these detailed facts we deduce the existence of important libraries associated with a particular person. The importing of the Chinese process for fabrication of paper and its progressive diffusion in the large metropolises of the East in the course of the second/eighth and third/ninth centuries gave a vigorous impulse to the work of copyists who used henceforth a light, strong and less expensive material than papyrus and parchment. A veritable trade in manuscripts developed, supported by the eagerness of the cultured classes to find precious books.

Certain private libraries are known to us because of the richness of their collections. Possessions of princes, scholars, eminent people, they are sometimes opened to a traveller, a curious person, a friend of the sciences, and through this to the historian who thus discovers their existence. The courtier ʿAlī b. Yaḥyā al-Munajjim (d. 275/886) had put together a magnificent collection in his castle on the outskirts of Baghdad, and Yāqūt reports that the famous Abū Maʿshar stopped there when he was on the way to Mecca. Charmed by the books that he found, he abandoned the pilgrimage to devote himself to astronomy, an act of impiety for which the biographer discreetly reproaches him.[8]

The most remarkable sovereigns all sought to possess a rich library in their palace and thus to demonstrate a taste for knowledge, an indispensable quality of good government. But only certain of these libraries were open to the learned men who there accomplished their task as scholars, translators, commentators, compilers and authors and can be considered true scientific institutions; however, they offer on their shelves only a small part of the books copied, read, taught, commented on. Furthermore, the collections gathered must have included above all works on the religious sciences and great literature; the share of the exact sciences is impossible to establish in the absence of any catalogue.

For these reasons, particular attention must be paid to the creations of the *dār al-ḥikma* or *dār al-ʿilm* by the Shiʿite princes. Youssef Eche believed that it was possible to discern three periods in the history of libraries: first, that of the *bayt al-ḥikma* summed up in the famous foundation attributed to al-Ma'mūn; the second is that of *dār al-ʿilm*, while the third sees the passage of the *dār al-ʿilm* to libraries depending on the *madrasas*, *dār al-ḥadīth*, hospitals, mosques, etc. Although this classification which forces its way into the diverse foundations of the fourth/ninth and fifth/tenth centuries in the model of the Fatimid *dār al-ʿilm* is too systematic, it does at least have the merit of exploiting the role played by the Shiʿites in the creation of libraries destined to favour the development of all the sciences and without doubt to serve an active propaganda. In their palace in Cairo, the Caliphs had gathered rich collections; forty rooms were given to this use, if one is to believe the informant copied by al-Maqrīzī, and one found there 18 000 manuscripts treating the sciences of the Ancients. In 395/1005, al-Ḥākim founded the *dār al-ḥikma*, sometimes called *dār al-ʿilm*: in this magnificent library, enriched by supplies taken from the private collections of the palace, scholars, readers of the Qur'ān, astronomers, grammarians, lexicographers and physicians were established, teachers taught, scholars gathered. The Caliph had constituted *waqf* a certain number of lands in Fusṭāṭ in aid of several mosques and the *dār al-ḥikma*. A little more than a tenth of revenues were given to this last institution and had to be used to pay the librarian, the copyists, the domestics, to ensure the restoration of books, to provide readers with ink, paper and calamus, to buy carpets and hangings. This budget entirely devoted to the library did not take into account other spendings, wages of scholars attached to the establishment and expenses of teaching. Is this to say that these charges were deducted from other funds? Or that, in reality, the *dār al-ḥikma* functioned essentially as a library open to all disciplines and a wide public? If this institution was not, at the time of al-Ḥākim, the seat of Ismaeli propaganda, it became that subsequently and knew then a turbulent history.[9]

In Mosul, Basra, Aleppo, Tripoli, Baghdad, similar foundations played the same role: libraries ensuring the conservation and the copying of manuscripts, centres for instruction and the spread of the sciences and ideas, places for meetings and discussions, sometimes board and lodging for scholars and pupils. Such was the *dār al-ʿilm* founded by the Buwayhid vizier Sābūr b. Ardashīr in 381/991 or 383/993 in the area of al-Karkh in Baghdad. The introduction of the catalogue, alas the only piece preserved, shows that, besides the Qur'ān and works of commentary, of *fiqh*, of theology, of genealogy, of grammar, of poetry, one finds 'books of the people of the Family', i.e. books of Shiʿite orientation composed by descendants of the Prophet, and manuscripts on medicine, astronomy, philosophy and other sciences. Widely equipped with *waqfs* this library prospered in the first half of the fifth/eleventh century but burnt down in 447/1055 (according to some) or in 451/1059 (according to others) in the course of a fire that ravaged the whole area.

In so far as the great libraries of the fourth/tenth–fifth/eleventh centuries were able to support the spread of heretical doctrines and were open to intellectual movements of thinkers judged as innovative, they were familiar with confiscations and destructions when the Sunni orthodoxy triumphed. At the time of the conquest of Rayy by Maḥmūd b. Ghazna in 420/1029, this sultan whose fight against all forms of heterodoxy guided policy banned the Muʿtazilites and burned their books, as well as those of the philosophers and astronomers that he found in the library founded by a Buwayhid emir; he confiscated the other works which he sent to his capital, Ghazna, to enrich his own library. The treasures accumulated by the Fatimid Caliphs were likewise liquidated and dispersed on the accession of Saladin. An eminent biographer of this sovereign extracts some juicy details on the operation:

> The auctions took place two days in each week, and all was given at the lowest price ... The books were pulled out of their cases ... and everything was mixed up: books of literature were placed with those of astronomy, those of theology with those of logic, books of medicine with treatises on geometry, histories with commentaries on the Qur'ān, unknown volumes with the famous.[10]

## THE FIRST HOSPITALS

Of all the scientific institutions, the hospitals are the most easily spotted in so far as the sources and the vocabulary identify without ambiguity the *bīmāristān*. This word of Persian origin indicates an establishment where the ill were welcomed and cared for by qualified staff; they are distinguished in this way from different forms of hospices, asylums, lazarets, leper-houses with which the medieval East was familiar and by which society was seeking more to protect itself from the sick or the mad, by isolating them, than to offer them any way to a true cure. But it is difficult to outline a history of the hospitals since our sources, in the majority of cases, only make mention of the founding of a hospital, and rarely say what was the real activity and the duration of an establishment. The works of Lucien Leclerc and Aḥmad Issa Bey[11] are particularly involved in putting forward the number, modernity and comfort of these prestigious buildings. Thus, the data by al-Qalqashandī and al-Maqrīzī identifies about ten hospitals founded in Cairo between the third/ninth and ninth/fifteenth centuries; the list is impressive and leaves one thinking that the Egyptian capital benefited from an infrastructure of hospitals of the first order. Yet al-Maqrīzī himself indicates clearly that at the mercy of political vicissitudes and urban reconstructions certain establishments knew only a brief, indeed fleeting, life.

Without doubt it is on Hārūn al-Rashīd (170/786–193/809) that the merit falls for having founded the first hospital to have functioned in the Islamic world. If one is to believe the remarks recorded by al-Qifṭī, the physician Jibrā'īl b. Bakhtīshūʿ, called from Gundīshāpūr to Baghdad, received an order from the Caliph to create a *bīmāristān* in his capital. The Persian origin of this term and the role played by the physicians from Gundīshāpūr led to the assumption, long held, that the hospital of this great centre of Persia served as a model for the first Arab establishments. Current research turns in other directions: isn't the place of Gundīshāpūr in the history of the beginnings of Arabic medicine excessive?[12] Wouldn't the *bīmāristān* be a replica of the Syriac *xenodochion*? And wouldn't its founding by such a vizier or caliph have been to enrol in a framework of rivalry between the medical movements which faced each other in the first Abbasid century?[13]

In the third/ninth and fourth/tenth centuries, constructions multiplied in the Abbasid capital, all born from the goodwill of a sovereign, a vizier, a man highly placed in the Court. They are proof of the vitality of medical activity, still widely in the hands of Nestorian Christian scholars. Thanks to the study by Guy le Strange on the topography of Baghdad, adapted for hospitals by Arslan Terzioglu, it is possible to make a map.[14] The most prestigious was the *bīmāristān* al-ʿAḍudī. Whilst he was the emir in Shīrāz ʿAḍud al-Dawla (338/949–372/983) appraised the competence of the physician Jibrāʾīl b. Bakhtīshūʿ, grandson of the doctor to Hārūn, whose treatise on the nerve of the eye he had admired. Having become master of Baghdad, this Buwayhid sovereign charged Jibrāʾīl to construct a hospital, wanting without doubt to affirm with a luxurious foundation the prestige of his capital. What is known about this establishment, erected in 371/982 on the western bank of the river at the side of the old ruined palace of Khuld, justifies its renown. The emir allocated to Jibrāʾīl a double salary of 300 dirhems per month, for his functions at the Court and his work in the hospital. A staff of twenty-four physicians, of whom certain were specialists in ophthalmology, surgery and orthopaedics, was attached to it. Ibn Abī Uṣaybiʿa has preserved for us the memory of several of them: Ibrāhīm b. Bakus, although he became blind, continued to practise medicine; he also gave lessons in this hospital to provide for his needs. Ibn al-Ṭayyib too treated the sick and taught medicine; he was notably the teacher of Ibn Buṭlān; the biographer claims to have seen an example of his commentary in a treatise of Galen proving that the reading had been done under his direction at the hospital al-ʿAḍudī in Baghdad on 11 Ramaḍān 406 (22 February 1016). This foundation was endowed with quite important revenues to ensure its longevity: Ibn Jubayr, crossing Baghdad at the end of the sixth/twelfth century, saw this hospital still in use, even though it was only visited by physicians twice a week.

Before the fifth/eleventh century, we only knew of the establishment of care in the large metropolises: Baghdad, Cairo, with a foundation due to the Tulunids, Rayy perhaps, where it is said that al-Rāzī was hospital director before he came to the Abbasid capital, and some other cities of Iran.

## OBSERVATORIES AND OBSERVATION POSTS

These prestigious capitals attracted yet more scholars, astrologers and astronomers, certain to find support and bonuses in the Court. The introduction of rigorous methods, geometric models and mathematical formulae, notably after the translation of the *Almagest* of Ptolemy, produced a rapid growth in astronomy based on observation. Witness the great number of numerical tables, accompanied by explanations sufficient to allow the astronomer or astrologer to solve the problems of his profession. The instruments used to this end are relatively well known to us, thanks to the treatises which expose the meticulous rules governing their construction. However, the places where their astronomers conducted their works of observation, the scientific institutions which allowed their good progress, are difficult to discern, despite the efforts of Aydin Sayili to check all the observatories mentioned in the sources.[15]

A certainty imposes itself nevertheless: until the fifth/eleventh century the numerous works of observation attested in Baghdad, Isfahan, Cairo did not have for their setting observatories taking the form of special buildings, constructed to this effect, equipped with measuring instruments and designed to last several years, but what one could call observation posts, temporary, modestly equipped, with precise objectives. Thus, a number of astronomers used a private observatory, i.e. they equipped themselves with a few instruments; it is known that the famous Banū Mūsā observed the sky from their house situated at Bāb al-Ṭāq on the Tigris.

Several sovereigns encouraged astronomical works, often through an interest in astrology. It was thus for the enterprises patronized by Caliph al-Ma'mūn, one in Baghdad itself, in the al-Shammāsiyya area, and the other on the outskirts of Damascus on Mount Qāsiyūn. The greatest astronomers of the era were gathered together at the expense of this sovereign and charged with a precise programme of proving the data in the *Almagest* and of special observation of the sun and the moon for one year, which led to the establishment of the *Verified Tables*. But we have no description of specific buildings, and there is room to believe that the astronomers, with their measuring instruments, were established temporarily in the places indicated. There is no reason to link this cycle of observations to the *Bayt al-ḥikma*, whose functions amount to those of a library and a centre of translation. This scientific activity was conducted in the very last years of the reign of al-Ma'mūn; if the sources differ slightly with regard to the exact date, they agree in saying that all work ceased with the death of al-Ma'mūn in 218/833.

The Buwayhids and their viziers in their turn developed observation programmes based in Rayy, Isfahan or Shīrāz. Carried out with instruments of large dimension, difficult to transport, certain of these works needed appropriate installations, even though temporary. Thus the emir ʿAḍud al-Dawla, the same who gave his name to the great hospital in Baghdad, charged ʿAbd al-Raḥmān al-Ṣūfī, famous for his work on the fixed stars, with measuring the obliquity of the ecliptic. This operation took place in Shīrāz in 359/969–70 and was without doubt repeated in the following years, with the help of a ring several metres in diameter. As for his son, Sharaf al-Dawla, he had an observatory constructed in the garden of his palace in Baghdad. The term used by al-Qifṭī, *bayt al-raṣad*, leads one to think that exceptionally we are faced with a building constructed to a plan, with a director, and equipped for an astronomical programme.[16] Except for the inaugural observations described at length by the biographer, we unfortunately know nothing about the work which was carried out there. Once again will the death of the founder signify the end of an establishment?

The Fatimid Caliphs of Cairo, al-ʿAzīz and his successor al-Ḥākim, through their generosity allowed the astronomer Ibn Yūnus to make a series of observations which led to the compilation of the famous *Hakemite Tables*. This book is built on work over several years and on numerous measurements carried out in the scholar's own house and in other different locations in Cairo. In effect, as Aydin Sayili had shown by the meticulous reading of the sources, nothing proves that al-Ḥākim had an observatory constructed on Mount Muqattam to the east of Cairo. Nevertheless an assertion by al-Maqrīzī leads one to think that the Caliph possessed a house on this mountain to which he liked to retire in order to observe the sky. But this is not a matter of a great scientific institution at the service of astronomy.

## THE TEACHING OF THE SCIENCES

From princely and prestigious foundations, fleeting and concentrated in a few large metropolises – thus is sketched the tableau of scientific institutions during the first four centuries of the history of Islam. Born from the goodwill of sovereigns marked by heterodoxical movements of thought, without doubt they permitted the activity of scholars, favoured the development of the sciences and supported an élite of open mind. But they become obliterated behind the princes on whom they directly depended, behind the scholars who worked there: the men, more than the institutions, were the carriers and diffusers of ideas. Thus the teaching took place in a climate of great freedom, independent of all institution, even if, here and there, lessons were taking place in a library or a hospital, even if one reads, for example, that lessons in medicine were given in the mosque of Ibn Ṭūlūn in Cairo.[17] The sciences were transmitted by the very same people who were the artisans of their development. The scholars, most often in their own residence, more rarely in a public place, met the students, attracted sometimes from very far by the reputation of the master. Thus it is recounted that the physician Yūḥannā b. Māsawayh made the young

Ḥunayn b. Isḥāq go out 'of his house' because he disrupted the lesson with too many questions. In his fine study on the 'colleges' in Islam, George Makdisi emphasizes strongly the private and personal character of the teaching of the sciences, outside of any institution.[18] ʿAbd al-Laṭīf al-Baghdadī, a scholar of encyclopaedic knowledge who died in Baghdad in 629/1231–2, left in his *Autobiography*[19] an extremely lively picture of the methods of teaching in medieval Islam. On reading it it is easy to imagine the students gathered to study a treatise under the direction of a master who corrected errors of reading, developed the sense of the text and explained the obscurities with the help of his knowledge and experience. The first goal was to know by heart the content of a work, but only after having understood it, because memory accompanies but does not exclude the exercise of intelligence. This authoritative teaching therefore depended on the reading, commentary and memorizing of entire works: translations of Greek authors, treatises by Arab scholars with authority, or original works by the master himself. The attestation of hearing (*samāʿ*), sometimes giving license to the disciple to transmit in his turn the text studied (*ijāẓa*), came to sanction careful listening to the lessons of the master.[20] Thus Ibn Abī Uṣaybiʿa describes a copy of *Sixteen Books* by Galen which a student in Damascus made himself and on which the master put an attestation of reading.[21] Most often, the biographers are content to affirm: 'He learnt with so-and-so' (literally: 'read under his direction'). This phrase, which appears constantly in the works of *ṭabaqāt*, remind us that, in medieval Islam, the transmission of all knowledge rested on the value of received and repeated speech. To have followed the lessons of a famous teacher and to have tied bonds of dependence and friendship with an illustrious master, to have attracted pupils in great number and to have benefited his disciples with a profitable teaching, that is what placed a scholar in line with his peers and affirmed the breadth of his knowledge.

## THE TRANSFORMATIONS IN THE FIFTH/ELEVENTH CENTURY

The arrival of Seljuk Turks, marked by the conquest of Baghdad in 447/1055, signified profound changes in the history of Islam, and the tableau of scientific institutions presented in the previous pages was noticeably altered. The orthodox and religious policy of this new dynasty is in effect manifested by a fierce effort at Sunni rectification. The climate of intellectual effervescence was altered. With the 'closing of the door on personal reflection' in matter of law, the intellectual field contracted, the scholars withdrew onto a knowledge considered closed, their role was limited to applying and transmitting the received tradition.[22] This evolution also affected the history of scientific institutions: the setting up of *madrasas*, the creation of libraries adjoining pious establishments, the development of the system of *waqfs*, the multiplying of hospitals.

## THE *MADRASAS* AND THE SCIENCES

The *madrasa* is a new institution which dates from the fifth/eleventh century. Although there were some precursor establishments and whatever hypothesis is held concerning the model from which it is derived, one can consider that the first foundations are due to the vizier Niẓām al-Mulk (d. 485/1092). The *madrasas* went on to multiply throughout the Seljuk empire and beyond. They are schools designed to train personnel capable of carrying out administrative, religious and juridical functions, in the service of Sunni policy led by the sovereigns. Abū Isḥāq al-Shīrāzī, the first principal teacher of the *Niẓāmiyya*, recounted, following a journey that led him from Baghdad to Nishāpūr: 'There was not a town or village that I crossed without finding there one of my students exercising the function of judge, secretary or preacher'.[23] The ruling power intervened directly, not only in the creation of such establishments but also in the choice and remuneration of teachers. From our point of view in this book, the role of the *madrasas* seems insignificant. In effect, only the religious or traditional sciences, the Qur'ān, exegesis, *ḥadīth* and particularly *fiqh*, together with associated disciplines, were taught there. But to affirm, following all those who have studied the development of the *madrasas* in Islam, that the sciences of the Ancients were excluded is to leave unanswered the questions that the historian willingly asks himself: certain mathematical and astronomical learnings were necessary to men of religion and of law: through what means were they taught? Hasn't a part of Arabic science been progressively integrated into traditional learning? Hasn't the man of science, open to philosophy and speculative thought, given place to the specialist, physician, astrologer, engineer, *faraḍī*, *muwaqqit*, capable of rendering the services that society expected from him?[24] An observation is needed: some scientific disciplines were able to find a place in the *madrasas*. This is the case, indisputably, with the *farā'iḍ*; this science of successional shares, which calls for precise juridical rules and complex mathematical processes, was taught in certain *madrasas* because it was indispensable to the *faqīh*. In the list of teachers of the *Niẓāmiyya* drawn up by Asad Talas,[25] one notes two teachers of *farā'iḍ* and arithmetic, alongside twenty-three teachers of *fiqh* and *uṣūl*, seven of *tafsīr* and *ḥadīth*, thirteen of *kalām* and seven of *adab*. The case is less certain for astronomy; yet the art of determining the *qibla*, the hours of the canonical prayers and the beginning of the month of Ramaḍān raised astronomical questions that the *muwaqqit* could not ignore, and it must be supposed that the subject was studied in the *madrasas*. Some scholars, through choice or necessity, joined the teaching of scientific disciplines with those of law. Let us take the example of Kamāl al-Dīn b. Yūnus, who died in 639/1242 and was at the time a Shafiʿite lawyer and a mathematician of repute. He had studied the *fiqh* at the *madrasa Niẓāmiyya* in Baghdad; he became in his turn a teacher in various *madrasas* in his town of birth, Mosul. To his traditional teaching of the juridical disciplines, he added lessons in astronomy and mathematics; Ibn Khalliqān, who devoted to him a long highly laudatory note,[26] cites the accounts of disciples who studied with him, one studying the *Almagest* of Ptolemy, the other musical theory.[27] But in the absence of any official programme of instruction in the *madrasas*, these tenuous indications, gleaned here and there, do not give clear answers; rather, they invite us to undertake precise studies which, particularly for the second half of the Middle Ages, are lacking.

## ABOUT NEW LIBRARIES

The spreading of the *madrasas* changed the nature and place of public libraries. From the fifth/eleventh century the *dār al-ʿilm* and other independent libraries disappeared in effect from the urban landscape to make way for buildings annexed to other foundations, the first of which were the *madrasas*. Al-Qalqashandī, author of the eighth/fifteenth century, left us a remarkably perspicacious analysis:

> The caliphs and the sovereigns had in the past a lively interest in great libraries and paid them much attention, which allowed them to make up fine and numerous collections. It is said that the greatest libraries of Islam were the following three: the library of the Abbasid Caliphs of Baghdad ... the library of the Fatimid Caliphs of Cairo ... and the library of the Umayyad Caliphs of Spain. But today the sovereigns have only a weak interest in libraries; they are satisfied with the libraries of the *madrasas* because they are of the greatest necessity.[28]

It is possible to convince oneself of this evolution by looking at the succession of principal libraries of the Abbasid capital between the second/eighth and the seventh/thirteenth centuries: the *bayt al-ḥikma* of Hārūn al-Rashīd and al-Ma'mūn; some collections of bibliophiles at times accessible to scholars such as Yaḥyā al-Munajjim; the great library of Sābūr founded at the end of the fourth/tenth century, an institution of Shiʿite orientation open to all scholars without bias. In 459/1066, a few years after the fire at the latter, the *madrasa al-Niẓāmiyya* was inaugurated; a library renowned for its scholarly directors and for the richness of its funding, was annexed there. It was the same for the other *madrasas* in Baghdad. In the first half of the seventh/thirteenth century, erudite and well-read people went willingly to the *Mustanṣiriyya* famous for its collections and manuscripts. Youssef Eche recorded about ten libraries dependent on *madrasas* between the fifth/eleventh century and the seventh/thirteenth century and about fifteen annexed to other religious foundations (mosque, *ribāṭ*, mausoleum, etc.). Because they were adjoining establishments of instruction in the traditional sciences, the nature of their collections must have reflected interests limited to the disciplines studied as well as the will of Sunni propaganda. Yet, it is known that the *Canon* of Ibn Sīnā (Avicenna) was admitted into the *Mustanṣiriyya* and that the physician Ibn Jazla had instituted his collection *waqf*, designating the mausoleum of Abū Ḥanīfa as the place for conservation. Recently a set of mathematical works, copied in the colleges *Niẓāmiyya* in Baghdad and Mosul in 556/1161, has been found. Anton Heinen, who published one of them,[29] supposes that the treatise was studied not for its astronomical and mathematical content but because the neatness and simplicity of the arguments formed an interesting example of reasoning; logic, he affirms, was considered as useful, indeed indispensable, discipline to one who studied the *fiqh* or the *kalām*. These few facts, scattered, again do not permit conclusions about the real role of the libraries of *madrasas* in the development of the sciences, but invite further work on this point.

## ENDOWMENTS IN *WAQFS*

Through the system of *waqfs*, not only the *madrasas* but many other establishments were granted revenues which ensured their function and freed them from dependence on a patron. In the fourth/tenth century, great libraries such as that of ʿAḍud al-Dawla in Basra, which passes as being the first established in *waqf*, were already benefiting from this system. But from the fifth/eleventh century every foundation of mosque, Koranic school, *ribāṭ*, *khān*, *madrasa*, hospital, was accompanied by an endowment in *waqfs*. Possessions, generally property – commercial premises, blocks of flats, baths, gardens, farm estates – were made up in *waqfs* and their earnings were allocated expressly by the founder as a work of piety or charity. Without ignoring the complex juridical problems of this system or the interrogations about the inauspicious role that it could have played in the economic evolution of the Arab world, we are forced to note that this style of financing favoured the activity and longevity of institutions of public interest.

One of the older examples preserved to us is in two documents edited by Mohammed Khadr.[30] They originate from a Qarakhānid prince from

Central Asia, Bughrā Khān, and concern the creation in Samarkand of a *madrasa* and a hospital in 458/1065–6. In the eyes of his contemporaries and descendants, Bughrā Khān was the ideal pious and orthodox sovereign who led the fight against the Shiʿites. The foundation of a *madrasa* comes from this policy, but also the construction of a hospital, as proof of the act of *waqf*.

## MULTIPLICATION OF THE HOSPITALS

Such a perspective can help us to understand the multiplication of hospitals in all the towns in the Near East, from the fifth/eleventh century, an unquestionable sign of the spread of a medical science for the service of the local population. In effect, it is precisely to this time that some new creations are associated in Wāsiṭ, Mayyāfāriqīn, Aleppo, Antioch, which signify the development of the following centuries. When Ibn Jubayr travelled the Near East in the years 578–81/1183–5, he noted one or more hospitals in the majority of cities that he passed through. Our Andalusian traveller asked a *shaykh* from Homs if one found there a hospital 'according to the usage of the towns of these regions'; he gained the impression that 'the hospitals are among the finest proofs of the glory of Islam, the *madrasas* are another'.[31] The majority of these foundations were due to the initiative of sovereigns animated by a social concern and desirous of prestige. The multiplication of autonomous dynasties, wishing to see their regional capital rival Baghdad and their Court to attract scholars and artists thanks to rich pensions, favoured a cultural and scientific development of which the Abbasid capital was once able one time to claim a monopoly. But these considerations do not explain everything: the growth in the number of hospitals cannot be separated in time and space from the spreading of the *madrasas*. Thus the construction of hospitals in Aleppo, Raqqa and Damascus by Nūr al-Dīn (540/1146–569/1174), contemporaneous with the foundation of *madrasas* and *khāns sūfīs*, combines with the effort of moral rearmament linked to the fight against Shiʿism and the crusaders. After his victorious entry into Damascus, this sovereign created numerous foundations including several *madrasas* and the famous hospital *al-Nūrī*; now the 'Museum of the History of Medicine and the Sciences', the fine building from the Zangid era reminds visitors of the splendour of medieval medicine in this town. At around the same time Turkey was endowed by the Seljuk emirs with establishments whose architecture impresses the traveller even today, but leaves the historian perplexed as to their use.[32] Schools for the teaching of religious sciences, the *madrasas* worked towards the strengthening of the soul; centres for healing and the training of doctors, the hospitals had to bring cures to the sick:

> 'You founded a *madrasa* and a hospital
> to set right religions and bodies.'[33]

Through these two lines, it is very plain, the poet was celebrating Sultan al-Manṣūr Qalāwūn; this sovereign that Mamluk propaganda presented as the unique *mujāhid* of his generation had had constructed in Cairo the famous hospital which bears his name and, fitting into the same architectural group, a *madrasa* and a mausoleum. Al-Maqrīzī left us a description of great interest and adds this valuable indication:

> When everything was finished, al-Mālik al-Manṣūr attributed to the establishment some *waqfs* as much to Cairo as in the rest of the country of which the revenue was raised to a million dirhams per year, and he designated the amounts which must be allocated to the expenses of the hospital, the mausoleum, the *madrasa* and the orphans' school.[34]

The act of constitution of *waqfs* corresponding to the endowments mentioned by al-Maqrīzī has been discovered in the Archives and deciphered by Ahmad Zeki Pacha; dated from 23 dhū al-ḥijja 684 (20 February 1285), it gives the list of forecast expenses for the hospital: wages of doctors, ophthalmologists, surgeons, makers of medicines, domestics and all the staff, purchase of remedies, food, equipment (beds, mattresses, bowls), perfumes, repairs to buildings. Thus generously endowed, this establishment of care was able to welcome for some centuries 'sick Muslims, men and women, the rich and fortunate as well as the poor and needy, from Cairo and the surrounding area, the residents as well as travellers . . . whatever the illnesses from which they were suffering, serious or slight.'[35]

Through their very existence the hospitals have played an essential role in the assimilation, the exercise of and the diffusion of medical science. All the great masters who were full of advice and instructions on the subject of learning medicine recommended students to frequent the hospital in order to complete the lessons by observation of the sick. The teaching of the sciences, as has been said above, was left to the initiative of the scholar who gathered around him some disciples, usually at his home. Ibn Abī Uṣaybiʿa, the author of a famous history of physicians, had the occasion in Damascus, at the start of the seventh/thirteenth century, to follow the lessons of al-Dakhwār of which he presents an interesting description in the note that he devotes to this eminent Syrian scholar.[36] After having visited his sick in the hospital and in the Court, this master gathered his students at his house; one of them was charged with reading a medical treatise whilst he himself followed using another copy of the text, correcting the reading if necessary, enriching it with explanations and discussions adapted to the capabilities of each. Towards the end of his life, al-Dakhwār instituted in *waqf* his house situated in the jewellers area in order to establish a school of medicine there; he allocated for its maintenance and for the payment of teachers and students the revenues from the properties that he possessed. He designated al-Raḥbī, another eminent physician, as his successor. In 628/1231, the latter gave an inaugural lesson there, before an audience of scholars and jurisconsults. Various professors practised in their turn at this establishment, named, it would seem, by the sovereign of Damascus. Two other schools of the same type existed, according to the chapter that al-Nuʿaymī, author of a history of *madrasas* of Damascus, devotes to 'medical *madrasas*'.[37] Such foundations are the sign of major development in the Syrian capital in the seventh/thirteenth century; they demonstrate the desire of the Ayyubid princes and then the Mamluks to continue the tradition of the patron; they show that medicine, considered as a very useful discipline, held a particular status and that its teaching developed further than that of other sciences, to practical ends.

## HOSPITALS AND THE TEACHING OF MEDICINE

This is why the hospitals, or at least the largest of them, have become, through the goodwill of their founder, centres for the learning of medicine. Thus Nūr al-Dīn equipped the hospital of Damascus with a fine library designed to support the spread of teaching in this place. Ibn Abī Uṣaybiʿa evoked in these words the activities of an eminent Syrian doctor of the sixth/twelfth century: after examining the sick in the hospital and going to the palace to treat the important people in the Court,

> Abū al-Majd b. Abī al-Ḥakam sat in the great *īwān* of the *bīmāristān*, fitted with carpets, in order to study there. Nūr al-Dīn had, in effect, instituted in *waqf* to the profit of this *bīmāristān* a great number of works on medicine arranged in two cases which adorned the centre of the *īwān*. There, all the doctors and students came to him; medical questions were discussed and the pupils learnt (under his direction). After having worked, discussed and read for three hours, he returned home.[38]

This biographer has left us the memory of many other renowned doctors who taught in this Damascan hospital. Also, one knows from al-Maqrīzī that the hospital al-Manṣūrī in Cairo possessed 'a place where the head doctor sat to give lessons in medicine'.[39] This corroborates the decree of nomination of a certain Muhadhdhab al-Dīn, head doctor, as teacher attached to this establishment.[40] In this diploma, the sovereign was glad to have led the *jihād* and put into the framework of this orthodox activity the nomination of teachers of the sciences of medicine, *fiqh*, *ḥadīth*, Qur'ān. Such arrangements leave one to think that medicine, as a scientific discipline and subject of instruction, would have progressively lost its place among the ancient sciences in order to integrate itself, as a practical and useful science, into the Islamic culture. The institution of *waqfs* in great numbers for the profit of the hospital confirms this evolution.

## THE GREAT OBSERVATORIES OF MARĀGHA AND SAMARKAND

The fifth/eleventh century marks the appearance of ambitious and costly foundations in the field of astronomy; but in contrast to the hospitals these remain exceptional. One of these observatories that the Fatimid vizier al-Afḍal had built in 513/1119 holds our attention first. We owe to al-Maqrīzī a detailed description of the vicissitudes that this construction met: the repeated failures of the copper casting, the will to build instruments of a large size to obtain greater precision in measurements, the delays in the locating of the great circle, the abandoning of the project after the death of the vizier, the hostility of the people.[41] All these difficulties of a grandiose project leave one to think that the observatory was not at this time a known and integrated institution.

The subsequent great observatories of Marāgha and Samarkand are in comparison successes which mark both the outcome of the earlier tentative research and the development of an astronomical science duly patronized by some sovereigns without doubt attracted by astrology.

In Marāgha, a town of Azerbaijan near the lake of Urmiya, a great observatory was built, the foundation walls of which can still be seen today. The initiative for this construction is down to Hūlāgū, the grandson of Gengis Khān, who conquered and sacked Baghdad in 656/1258. The contrast between these two images, that of the head of the devastating Mongol armies and that of protector of the sciences, is unexpected. In fact, once the waves of violence and destruction had passed, once the domination of the conquerors was assured in the Near and Far East, the Mongols quickly assimilated and integrated the language, religion and culture of the conquered people. In their turn they developed a civilization which remains mainly ignored by historians more inclined to evoke the military and political episodes of the Mongol epic.

Yet the certain interest of Hūlāgū for the sciences, astrology notably, made him take into his service one of the greatest astronomers and mathematicians that Islam knew: Naṣīr al-Dīn al-Ṭūsī. This scholar was taking refuge close to the Court of the Assassins, in the fortress of Alamut. It is there that Hūlāgū came to look for him to charge him with building an observatory. The work commenced in 657/1259 and lasted some years; it was extremely expensive and Naṣīr al-Dīn had more than once to justify the expenses incurred. Situated on a hill near to the town of Marāgha, the imposing buildings occupied an esplanade of some 150 by 350 metres; the descriptions mention with admiration a dome with a hole in the top to allow the sun's rays to pass and a library of 40 000 volumes that the Mongol armies had plundered from Iran, Syria and Mesopotamia. Our most precise information concerns the instruments that were used there, because their constructor, al-ʿUrḍī, wrote a small treatise on this subject. But, once again, our sources hardly allow us to represent this foundation and its function precisely.

Twelve years of observations and calculations led to the production, in Persian, of the *Ilkhanide Tables*, finished in 669/1271. The question of a continuation of these first works and of the elaboration of new tables remains obscure. A great number of scholars were attached to the observatory directed by Naṣīr al-Dīn al-Ṭūsī until his death in 672/1274 and then by his sons. Nearly twenty names are familiar to us. Certain of them, such as Fakhr al-Dīn al-Akhlāṭī, from Anatolia, worked at Marāgha during the whole period of activity of the institution. A tradition claims that some Chinese astronomers were joined to them and brought some knowledge of the Chinese methods of computation. With its important group of scholars and its immense library, the observatory of Hūlāgū was an institution for astronomical research, an academy where scientific contacts were made and a centre where the students came to be educated. It is reported that Naṣīr al-Dīn had about a hundred disciples. But we do not know how the education was organized. It is said of Abū al-Faraj (Barhebraeus) that he taught at Marāgha the *Elements* of Euclid in 668/1270 and the *Almagest* of Ptolemy in 670/1272; but it is not clear whether these lessons took place in Arabic at the observatory or in Syriac at the monastery in the town. Both hypotheses are plausible.

Marāgha is the first observatory of the Muslim world that benefited from revenue in *waqfs*, which caused, it would seem, some protests, because it was not a pious or charitable institution. Thus endowed, the establishment did not suffer with the death of its founder (in 663/1265) and its activity continued at least until the beginning of the eighth/fourteenth century, since in 704/1304–5 one of the sons of Naṣīr al-Dīn was appointed as the director of the observatory. But three decades later the geographer Ḥamd Allāh al-Qazwīnī only saw ruins.

Nevertheless these remains must be impressive as their visit by the young Ulugh Beg inspired the latter, when he became governor of Transoxania, to construct an observatory similar to the one in Samarkand. In the ninth/fifteenth century, under the reign of the Timurid sovereigns, this metropolis knew a cultural and artistic development which made it the most flourishing centre in the whole of the Near East. Ulugh Beg, grandson of Tīmūr (our Tamerlan), was himself, if not a great scholar, at least a prince keen on the sciences liking to surround himself with scholars and to debate scientific questions with them.

In order to establish new astronomical tables, he had an observatory built, probably in 823/1420. Some debris was discovered in 1908, on a plateau at the northeast periphery of the town, by the Russian archaeologist K. L. Vjatkin; the first campaign of excavations was succeeded after the Second World War by another campaign of great interest; the results were published, in Russian, under the auspices of the Academy of Sciences of Uzbek and resulted in the restoration of the preserved part, essentially a fragment of the gnomon of great size used to determine the height of the sun from the length of the shadow. One sees also the remains of a building of cylindrical shape but with a complex interior plan; the decoration with enamelled squares is identical to that of the *madrasa* of the town built in the same era. It is known through ʿAbd al-Razzāq that one could see a portrayal of the ten celestial spheres with degrees, minutes, seconds and tenths of seconds, the spheres of rotation, the seven moving planets, the fixed stars and the terrestrial sphere, with climates, mountains, seas, deserts, etc. But the words used by the Persian chronicler give the impression that it was not globes, as at Marāgha, but maps and murals. The observatory of Samarkand could be considered as the most important in medieval Islam. Just as at Marāgha, numerous scholars were attached there, observations were made there for almost three decades and an enormous labour was accomplished which resulted in the compiling in 841/1437 of tables again called the *Ilkhanide Tables*. They give the results of an important collective work, but contain no new research on the subject of astronomy. They were very much used, and about hundred copies still exist.

Once again the lack of sources and the absence of precise monographs hardly allows us to portray the function of this institution. In particular, we are not familiar with its mode of financing, we do not know if education was administered there, we do not know if the library of Ulugh Beg was situated in the palace of the sovereign or annexed to the observatory. Among the men of science who became famous at Samarkand, Qādī-Zāde played an important role whilst he was at the head of the *madrasa*. It seems that lessons in mathematics, astronomy and medicine were given in this school, and it is reported that Ulugh Beg himself willingly went there to participate in the debates. Nevertheless, the links between these two institutions, the *madrasa* and the observatory, are not clear, and it is difficult to define the mission of the first in the spread of the exact sciences.

An account by the astronomer al-Kāshī nevertheless sheds some light on this extremely lively scientific environment. After having led an errant and impoverished life in search of financial protection, this scholar settled in Samarkand from where he sent a letter to his father who was still in Kashan.[42] He boasts freely about his professional triumphs and claims to have immediately aroused the admiration of everyone. He reports that he noted, at the time of his arrival at Samarkand, that all the instruments of observation that have been made for the observatory, or are in the course of being constructed, use an out-of-date concept and that he must make others. The numerous collaborators who surround Ulugh Beg only arouse his contempt, except for Qādī-Zāde. All his praise goes to the sovereign, his new protector, whose erudition, knowledge of mathematics and astronomy and role in the development of the sciences he emphasizes. But this interest of Ulugh Beg remains unexplained; whatever the reasons variously advanced it is certain that he maintained a climate of free discussion, himself participating in frequent scientific meetings that al-Kāshī is pleased to evoke. In reading the letter, it appears that the intellectual movement, in the ninth/fifteenth century as in the third/eighth century, depended directly on the favour of the prince. The death of Ulugh Beg in 853/1449 effectively put a stop to the activity of the observatory, and al-Qūshjī, the last astronomer to work there, then left Samarkand for Constantinople.

The assessment is clear. Although there was an enormous work in the field of astronomical observations, the observatories, as specialized foundations, were less numerous, without any doubt because, contrary to other scientific and cultural institutions, library, hospital, *madrasa*, mosque, they were only exceptionally considered as pious and charitable institutions, whose constitution in *waqfs* assured their place in the society and civilization of medieval Islam.

The evolution, outlined in this chapter calls for some final remarks. The exact sciences only benefited slightly from the integration into the urban landscape and into the traditional sciences of new institutions and official instruction; without doubt they were also transmitted less and less. Only the hospitals, as works of charity, and medicine, as a useful science, knew a remarkable diffusion. Some notable exceptions, such as the great observatories of Marāgha and Samarkand, hardly alter this picture.

But some regions outside our description, Turkey, the Maghreb (northwest Africa), Andalusia, knew a different history. While Seljuk Anatolia saw a great number of pious and charitable constructions and this tradition was maintained in the territories under Turkish domination, the Muslim West maintained a diversified scientific activity independent of every institution. One does not find any observatory there worthy of the name; the system of *madrasas* took root late on; the first hospital constructed in Spain was in Granada in 768/1366–7. These observations, although very brief, are of great importance in so far as Spain was the place of cultural contact between Islam and Christian Europe; which must lead one to look with a fresh eye at the influences of the Arabic scientific institutions on their equivalents in the West, an issue that we have made no pretence of tackling here.[43] In order to explain the great diversity that we observe, in time and space, it would be necessary to investigate the place occupied by the exact disciplines in the Arabo-Muslim cultural scene and the relationships that the different powers were maintaining with this field of knowledge. A history of the sciences that would do justice to this problem still largely remains to be done.

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## NOTES

1 M.-G. Balty Guesdon, (1992).
2 Ed. Cheikho (1911: 48).
3 Eche (1967: 31 *et seq.*).
4 On cultural life in the fourth/tenth century, see Kraemer (1986).
5 According to Micheau (1988) and (1992).
6 Ed. Beirut (1965: 655).
7 *Ibid.*, p. 560.
8 Ed. Margoliouth (1907–27: V, p. 467).
9 On the libraries in the Fatimid era, see Wiet (1963).
10 Cited in Wiet (1963: 10).
11 Leclerc (1876) and Issa Bey (1928).
12 L. Conrad and V. Nutton (Wellcome Institute for the History of Medicine, London) are preparing an important explanation on Gundīshāpūr which will take into account legendary tradition and historical reality.

13 This is the approach of the study by Dols (1987).
14 Le Strange (1900) and Terzioglu (1974).
15 Sayili (1960).
16 Ed. Lippert (1903: 79).
17 Ed. Būlāq (1853–5: II, p. 267).
18 Makdisi (1981: especially pp. 75–6).
19 Preserved in Ibn Abī Uṣaybiʿa, ed. Beirut, p. 683 *et seq.*
20 On the diplomas in reading, see the important work of Vajda (1983). See also Sublet (1991: 126 *et seq.*).
21 Ed. Beirut (1965: 670).
22 See, amongst others, the work by Arkoun (1975: 13–49).
23 Cited in Wüstenfeld (1891: 94).
24 This question is tackled in Sabra (1987).
25 Talas (1939).
26 Transl. Mac Guckin de Sane (1968: III, 466–74).
27 Another example is that of Ṣadr al-Dīn b. al-Wakīl (d. 716/1316) who taught under the cover of *ḥadīth* medicine, philosophy and the *kalām*. See Makdisi (1981: 78).
28 Ed. Cairo (1913: I, p. 466).
29 Heinen (1987).
30 Khadr (1967).
31 Ibn Jobair, vol. 2, p. 298, and vol. 3, p. 330.
32 A good example of this uncertainty: Cantay (1982).
33 Cited in Issa Bey (1928: 42).
34 Ed. Būlāq (1853–5: II, p. 406).
35 According to same terms as the act of *waqf*, cited in Issa Bey (1928: 154).
36 Ed. Beirut (1965: 728–35).
37 According to Makdisi (1981: 313 n. 38).
38 Ed. Beirut (1965: 628).
39 Ed. Būlāq (1853–5: II, p. 406).
40 Arabic edition in Muḥyī al-Dīn ibn ʿAbd al-Zāhir, *Tashrīf al-ayyām wa-l-ʿuṣūr. Sīrat al-Malik al-Manṣūr*, Cairo, 1961: 228–30. Translated in Micheau (1981: 123–5).
41 Ed. Būlāq (1853–5: I, pp. 125–8). Translated in Bouriant (1895: 366–9).
42 See Kennedy (1960).
43 For a criticism of an Islamic model at the origin of the development of the hospitals of the Latin West, see Jacquart and Micheau (1990: 243–51).

# 30

# *Classifications of the sciences*

JEAN JOLIVET

One finds in the variety of the writings in Arabic multiple ways of classifying the sciences; one must then say the 'learnings' to use a term whose wider meaning corresponds better to that of the word *ʿilm*. This can be a classification of a librarian or a bookseller, as in the *Fihrist* by al-Nadīm;[1] of a specialized lexicographer, as in the *Mafātīḥ al-ʿulūm* by al-Khwārizmī al-Kātib;[2] of a theologian: thus al-Ghazālī in his *Revivification of the Sciences of the Faith* divides them into 'science of conduct', i.e. about the relationships with God and men (*ʿilm al-muʿāmala*) and 'science of the mystical unveiling' (*ʿilm al-mukāshafa*).[3] It is here that one could call the classifications synchronic in that they propose a more or less loose system of learnings considered in their reciprocal relations. Others divide them up diachronically just as in stages of progressive acquisition or in educational methods; thus proceeds Ibn Ḥazm in the first classification of his *Organization of the sciences* (*Marātib al-ʿulūm*);[4] he there outlines a programme of studies which start at 5 years with language and the Koran and continue until the acquisition of a sort of rational theology. All these divisions reflect and tend to reproduce the fundamental beliefs of the society where they have been elaborated and its great cultural leanings; that much is evident in the case of religious and educational classifications but it is true also of others though in another way: the *Fihrist* and the *Mafātīḥ* have almost the same table of contents, starting with the traditional Islamic sciences and continuing with the sciences of a foreign origin. A same general structure governs the classifications by encyclopedists such as the Brothers of Purity[5] and of a historian such as Ibn Khaldūn.[6] It is evident that we have not to consider here these diverse genres but only those which tend to range in an order resulting from its nature a corpus of learnings which are sciences in the sense where this word has been employed throughout this work.

## I

That which we take up first is due to the philosopher and universal scholar of Islam, Abū Yūsuf Yaʿqūb b. Isḥāq al-Kindī (third/ninth century). Of his abundant work – the *Fihrist* enumerates close to two hundred and fifty works[7] – only about a tenth remains; but we know, either by direct reading or otherwise, that he wrote about philosophy and logic and also on the diverse mathematical sciences, medicine, meteorology, etc., briefly on principally Greek subjects; he was also involved in Islamic theology but relatively little.

Moreover, among the titles of the books on philosophy, there are four which are of interest to our subject; these are, in the order of the text: *Epistle on the Fact that One Only Comes to Philosophy through Mathematics; Book on the Order of the Books of Aristotle; Book on the Quiddity of Science and its Parts; Book on the Parts of Human Science.* Only the second work has reached us, under a slightly different title, and it contains indications of what, in all likelihood, was developed in the other three; above all it is an extensive exposition on what al-Kindī thought as regards the classification of the sciences.

This work therefore is entitled *Epistle on the Number of Books by Aristotle and on What is Required to Study Philosophy.*[8] We see first how the different parts are arranged, each of which contains elements which will interest us.

1 After an address to the addressee, not named, of the letter, al-Kindī enumerates the books by Aristotle; the most interesting is the classification which he gives them: books on logic, books on physics, books on the soul (this word does not appear; he says: 'on that which does not depend on nature, which exists by its own essence without having need of bodies, but exists with them and joined to them'), books on theology (in the Aristotelian sense; here again al-Kindī uses a paraphrase, 'on that which does not need the body and is not joined to it', without naming the science in question); later on will be added the books on morals and a 'quantity of books on particular subjects'.[9]

2 Then he develops a remark made quickly before even this enumeration: it is necessary to start with the science of mathematics, i.e. in the order arithmetic, geometry, astronomy, music.[10]

3 The group of things to know is made up of the science of substance and its attributes, itself conditioned by the science of quantity and quality, which are the attributes of substance from which derive all the others; it is in this science which philosophy consists.[11]

4 The science of the philosophers, or human science, differs from the science of the prophets, or divine science, in that the prophet immediately receives from God knowledge which demands much time and effort from the philosopher.[12]

5 Human science, being above simple appreciable knowledge, requires knowledge of quantity and of quality; the first consists of arithmetic (*ṣināʿat al-ʿadad*: 'the art of the number'), the science of quantity taken separately, and the science of harmony (*ʿilm al-taʾlīf*), the science of the relationships between numbers and of their compositions; the second, of geometry, the science of immobile quality, and astronomy, the science of mobile quality, i.e. of the shape of the world and of the movements of the forms which make it up; but the order to follow in the study of the sciences is that of progressive complication of their subjects: therefore, arithmetic, geometry, astronomy, harmony.[13]

6 It is therefore necessary to study successively: the books on mathematics, in the order that has been said; then the books on logic; then on physics; then metaphysics ('that which is beyond natural things'); then the books on morals; the other sciences deriving from the former ones.[14]

7 Finally al-Kindī explains successively what had been the aim of Aristotle in each of his books.[15]

Independently of the fact that the developments follow on from each other totally naturally, the plan of this *Epistle* is clear, and, above all, significant. The first and last parts respond to the plea of the addressee ('you asked me for information on the books by Aristotle'); the *Epistle* could have confined itself to this; but al-Kindī does not say that the books by Aristotle contain the whole of science. He even insinuates the contrary in his preamble, saying that one finds in these books 'a large part' of what is necessary to learn philosophy; he adds that his work contains more than he had been asked. The group of sciences therefore exceeds the contents of the Aristotelian corpus. Moreover the central part (4) takes into account the polysemy of the word *ʿilm* that was signalled at the beginning; more precisely it reserves the rights of a knowledge of divine origin – an interesting position on the part of a philosopher who elsewhere defends the very principle of philosophy against the attacks of the men of religion.[16]

That said, and to come to what properly concerns the classification of the sciences, one remarks that al-Kindī takes into account the essential and systematic order, and the didactic order. It is this last that inspires the central idea of the *Epistle*; it is necessary to start with mathematics. The Pythagorean classification of the mathematical sciences (5) regulates itself on an essential structure: the duality of the prime attributes of the substance, quantity and quality. But the programme which follows it immediately appears to take into account above all educational method. And (6) integrates into a programme of studies the synchronic list given in (1), preceded now by mathematics. As regards the series of sciences enumerated in this *Epistle*, it is divided into two groups comprising respectively the contents of the works by Aristotle and the mathematical sciences. It corresponds to a part only of the rubrics under which the *Fihrist* arranges the works of al-Kindī, because it does not take into account theology (in the Islamic sense), nor medicine – it may be that the latter, as the specific sciences, includes implicitly the derived sciences mentioned in (6). It will be observed finally that the trait by which 'human science' only to be acquired progressively, distinguishes itself from the 'science of prophets', illustrates an idea that al-Kindī mentions also at the beginning of his *First philosophy* and of *Liber de aspectibus*: philosophy, the sciences, develop themselves throughout the ages and express themselves in different languages.[17] Thus the successive nature of their acquisition is not only the work of each, it is also that of humanity in its entirety. Thus the sole work of al-Kindī which concerns the classification of the sciences and has reached us explains well the situation in which the author found himself: in the difficulty of beginnings. Faced with new results in his epoch – an abundant scientific and philosophical corpus and, in its detail, sometimes heterogeneous, resulting from methods also received as new but which had been practised throughout several centuries – al-Kindī had to conceive at the same time of a system, a history, an educational method, according to suggestions coming from different directions, without succeeding in really overcoming these differences. As a result this *Epistle* is at the same time precise and confused, and whose complexity itself is significant.

## II

We shall perhaps never know whether al-Kindī finally succeeded in considering as a system or according to the progression of an apprenticeship the multiplicity of sciences which were known to him. On the other hand, we know what his first great successor did, to whom will be given the title of 'the second Master' (the first being Aristotle), Abū Naṣr al-Fārābī (ob. 339/950). We are going to examine, by limiting ourselves to essentials (because many historical and epistemological problems crop up otherwise), his treatise entitled *Enumeration of the Sciences* (*Iḥṣā' al-ʿulūm*).[18]

The preamble[19] names five principal sciences: the science of language, the science of logic, the group of mathematical sciences, physics (literally, natural science), political science. He also announces there the respective parts that we are going to see now in greater detail by following the treatise itself.

1 The science of language comes in two sorts: on the one hand 'the memorizing of expressions which give a meaning for one nation and the science of what each one means'; and on the other hand the science of rules which govern these expressions (generally speaking, explains al-Fārābī, the rules are what constitutes an art). In each nation the science of the language divides into seven major parts: the science of simple expressions (i.e. words), the science of complex expressions (i.e. phrases), the science of rules which govern simple expressions, that of rules of compound expressions, that of rules to write well, to read well, and the science of verse. Each of these seven rubrics comprises developments, generally specific to the Arabic language, which are of little importance in our aim.[20]

2 The science of logic – which al-Fārābī calls, from one line to the next, science, and then art – gives the rules which allow one to think correctly and according to the truth, to protect oneself against mistakes, to check the thoughts where one could have made a mistake. It comprises eight parts: three which concern the diverse kinds of reasonings and expressions by which one forces oneself to think straight, and five for the skills which govern the diverse sorts of speech (demonstrative, dialectic, sophistic, rhetoric, poetic). Later al-Fārābī puts these parts in relation to eight treatises by Aristotle: the *Categories*, the *Peri Hermeneias*, the *Prior Analytics*, the *Posterior Analytics*, the *Topics*, the (*Refutations*) *Sophistics*, the *Rhetorics* and the *Poetics*.[21] He insists on the importance of the fourth part, which contains 'the rules to examine demonstrative statements, the rules of things with which philosophy is concerned and everything that leads its operations to their perfect accomplishment'; 'the three parts which precede it in the order of instruction (*fī tartīb al-taʿlīm*) prepare and lead there, and the four others depend on it'.[22]

3 Mathematical science (*al-ʿilm al-taʿlīmī*) comprise seven parts.

(a) Arithmetic (literally, the science of numbers), but this name is given to two sciences: practical arithmetic, which studies the numbers in so much that they are 'numbered' and that 'their number' must be taken in the bodies, is in use in commercial and civil relations; theoretical arithmetic studies the numbers taken absolutely, as they are in the mind, abstracted from the body and from every numbered thing, and their properties and the diverse relationships that they have with each other.[23]

(b) Geometry itself is either practical, or theoretical. Practically it considers lines and surfaces in the bodies worked by the various artisans. Theoretically, it considers the lines and surfaces taken absolutely, such as they are in general in all bodies; the latter itself is divided in two parts, that which considers lines and surfaces and that which considers solids. This last is subdivided according to the diverse sorts of solids. In every case these objects are studied either on their own, or according to their relationships.[24]

(c) Perspective (literally, the science of aspects, *de aspectibus* in Latin). It studies, like geometry, figures, sizes etc., inasmuch as they are found in lines, surfaces and solids, but it specializes in so far as it considers their ways of appearing to us, which differ from what these things truly are. It makes known the causes demonstratively and teaches about the processes which allow one to correct these errors and to proceed to indirect measures: in this sense it is also an art. It also studies rays, direct or reflected, by which things are seen.[25]

(d) The name astronomy is given to two sciences: the 'science of the decrees of the stars', which makes known future events and a large part of what is and has been; and the 'mathematical science of the stars', which studies the celestial bodies and their movements, and the earth.[26]

(e) Two sciences are called music: practical music, which has as its object sensible melodies, which are produced by the natural organs or by instruments; and theoretical music, which studies 'the causes of everything from which the melodies are composed', disregarding the subject and the instruments.[27]

(f) The science of weights considers them in as much as they are measured or are of use to measure (study of balances).[28]

(g) The science of industrious techniques (*ḥiyal*) is the application to natural bodies of all that has been demonstrated by mathematics. Here one first distinguishes the arithmetical procedures (*al-ḥiyal al-ʿadadiyya*), among which 'the science which one now calls *al-jabr wa-l-muqābala*': we recognize algebra, whose name in European languages comes from the first term of the Arabic expression. There exists next numerous geometrical procedures: the art of making constructions, the processes for measuring the different sorts of bodies, to fabricate astronomical and musical instruments, arcs, arms; to fabricate optical instruments, mirrors and to use these for different purposes (such as the construction of 'burning mirrors'); to fabricate 'marvellous vessels' (hydraulic mechanisms), and instruments of various techniques. All these sciences furnish the principles which are applied in the skilled craft trades (construction, carpentry, etc.).[29]

4 Physical science (*al-ʿilm al-ṭabīʿī*) considers natural bodies, their accidents, their causes. After a long analysis of the principles of the bodies, starting from artificial bodies and based on the postulated analogy between

the latter and natural bodies, al-Fārābī details eight parts to this science, which correspond to the same parts, authentic or not, of the Aristotelian corpus (*Physics*, *On the Heavens*; *On Coming-to-be and Passing-away*; *Meteorologica I–III*; *Meteorologica IV*; *On Metals*; *On Plants*; *On Animals*).[30]

5 Theology, or metaphysics (*al-ʿilm al-ilāhī*), is made up of three parts: 'the study of beings and things which are adventitious to them in so much as they are beings'; the study of the principles of the theoretical sciences: logic, mathematics, physics, their correct foundation and the refutation of invalid opinions; the study of incorporeal beings which are not in bodies (and al-Fārābī gives here the programme for a philosophical theology).[31]

6 Political science (*al-ʿilm al-madanī*) studies all that constitutes the behaviour and the ends of men, true and false happiness, relations between them and their styles of government. The royal function fulfilled correctly supposes the capacity to conceive of universal rules, and that which is acquired by experience; but these empirically determined conditions are satisfied by 'political philosophy', which provides the rules and the criteria for their determination. It includes two parts: one makes known what happiness is, and the other deals with the behaviour and good and bad practices of government etc.[32] To these developments whose Platonic and Aristotelian foundation is clearly visible, al-Fārābī juxtaposes immediately two others, on two disciplines whose Arabic names are convenient to use here and which have already been encountered: the *fiqh* and the *kalām*. Both are called at the same time 'science' and 'art'. The science of *fiqh* is thus the art which allows the unravelling of what the legislator, literally he who has instituted the law (religious), has not made precise, basing itself on the intention which directed this institution; corresponding to the two aspects of 'all religion', the science of *fiqh* includes two parts: one concerns concepts (*ārāʾ*), the other actions (*afʿāl*).[33] The science, or art, of *kalām* is the habitus, the stable disposition (*malaka*) which allows for the support of the concepts and the actions explicitly defined by the legislator. *Faqīh* and *mutakallim* have therefore different practices: the first 'discovers', starting with principles, that which the second 'reinforces' without adding anything.[34] Al-Fārābī adds to that a fairly long exposition on the different ways of putting the *kalām* into practice,[35] and his treatises finishes on this.

To explore just the questions and perspectives opened by this work, it would be necessary to have a long discourse. We restrict ourselves here to a certain number of observations which only touch on the classification of the sciences taken in the abstract. From the very beginning[36] al-Fārābī situates his work in time and place when he writes that '(his) goal in this book is to list one after the other the acknowledged sciences (*al-ʿulūm al-mashhūra*); one should note that he deals with the traditional sciences as well as the sciences of Greek origin, and that medicine is the great absentee of this treatise.[37] Moreover, still in his introduction, al-Fārābī seems to announce a system of the sciences (this is the meaning that can be given to the choice of the word *marātib*, which implies the ideas of order and degree), but he does not justify it, nor even explain it. It seems, however, that he proposes a table (synchronic order) rather than a programme (didactic order), which makes his plan clearer than that by al-Kindī.[38] As regards the traditional sciences, he appears original in relation to al-Khwārizmī al-Kātib, for example; not so much because he ignores the secretariat and the history which the latter included (and this neglect clarifies quite neatly his own concept of science), but because he systematizes the sciences of language and puts at the end what al-Khwārizmī had put at the beginning: the *fiqh* and the *kalām*. In addition these different sciences are relativized, in the sense that al-Fārābī describes what they are 'for every nation' or 'for every religion' in general (he seems to approach the sciences of language from his own historical situation). Thus he distances himself from the specifically Islamic *fiqh* and *kalām*.[39]

None the less, the chapters of this *Enumeration* are organized according to interlinking schemas. The first three (language, logic, mathematics) reproduce the system of liberal arts that had been slowly constituted in Greek Antiquity; in Chapters 2 and 3 one finds, but outside any programme explicitly marked as such, the two propaedeutic sciences of al-Kindī; Chapters 3, 4 and 5 take up the three theoretical sciences of Aristotle (see *Metaphysics* E, 1, 1026 a 19; K, 7, 1064 b 1–3), with a permutation of physics and mathematics which we will come back to. As for the sequence, logic, physics, theology, politics, one notices that it follows the order in which al-Kindī enumerated the works of Aristotle; but it is known that *Politics* was unknown in Arabic. However, we have seen al-Kindī cite works on ethics whose subject is related to that of political science, as al-Fārābī himself noted;[40] one knows the very special interest that he had in this subject. Anyway, one will note that here again mathematics upsets a traditional enumeration by its insertion; one may notice here specifically epistemological and historical questions which will be made explicit.

We have seen that several times al-Fārābī distinguished between science and art; and an art is made up of rules for which there is a science. There would thus be, in the end, two categories of sciences: the science of things (in the broad sense) and the science of rules. Generally he associates arts with each science, except with mathematics, physics, theology, i.e. with the three Aristotelian theoretical sciences. But it should be noted that this becomes complicated with regard to mathematics (once again): the *ḥiyal* are sometimes called arts, and arithmetic and geometry themselves each include a 'practical' science.

It seems that there are in this text some important Aristotelian structures with which contributions of another order come into conflict and cause their collapse. This is verified in another way; the content of certain sciences here is made up largely, even entirely, by the series of treatises by Aristotle. These sciences are logic, physics, metaphysics; one could think that, for al-Fārābī, the Greek philosopher took them to their perfection. But in the chapter on physics al-Fārābī starts by analysing artificial bodies, thus giving to this science, if not a new direction, at least a new horizon – that of fabrication, of practice, as has already been shown in the preceding remarks.

The way in which the structure of the *quadrivium* is at the same time conserved and broken down permits us to clarify the problem. The four original sciences retain there the respective places that they had in the *Republic*,[41] but 'perspective', optics, is inserted between geometry and astronomy; the science of weights and that of *ḥiyal* appear in the sixth and seventh rows. One sees two reasons for this appearance of optics, and in this place: first the important developments that it had known in Hellenistic, Roman and Arabic times; next, the fact that among other things 'it teaches about the distances of the celestial bodies and their sizes, from whatever place they are looked at, from the angles at which they are seen'.[42] The science of weights and that of *ḥiyal* integrates the successive progress in mechanics in the same eras. But extremely curious is the place given to what we call algebra, invented a century earlier by al-Khwārizmī, developed by among others al-Karajī, an older contemporary of al-Fārābī:[43] 'common to arithmetic and geometry', as he says, and presented in a relatively elaborate way,[44] it is just as well ordered among the industrious techniques, the *ḥiyal*; but the latter are put in relation, generally speaking, only with the 'natural bodies';[45] algebra is, actually, the only example which is given of 'arithmetical *ḥiyal*'. One understands with this example the difficulty of giving the correct place to a science that is so young and whose epistemological status has not yet been defined, the one given by al-Fārābī being doubly incongruous. We shall see these matters more clearly in the case of Avicenna.

Finally, it has already been noted that the mathematical sciences, which Aristotle placed between physics and theology, come here the first of three. Although al-Fārābī does not say that he has in mind a didactic order, it must be remembered that al-Kindī made the 'sciences of quantity and quality' propaedeutic sciences, with logic. It can be considered that al-Fārābī here takes up this point of view; the developments of mathematics, including their branches the most akin to reality (perspective, mechanics, *ḥiyal*), weigh indeed heavier, to place them before physics, than the Aristotelian classification, purely abstract, founded on the simple combination of two predicates applicable or not to the objects of these sciences (separate/not separate; mobile/immobile) and a probable trace also of the Platonic hierarchy of being, where numbers are situated between the visible and the Ideas. The sciences are arranged also according to their proximity to the real: synchronic order undoubtebly, but which expresses their effective relationships at a particularly complex time in their history.

## III

Abū ʿAlī al-Ḥusayn ibn Sīnā (370/980–428/1037), whose name is transposed with Avicenna in the Latin translations of the twelfth century, pondered over the classification of the sciences in the profound and original way that is his own. Let us mention two texts. The first is extracted from the most important of the encyclopedias which he wrote: *al-Shifā'*, where he gives his account of the subjects already studied by Aristotle; book VI is devoted to the subject dealt with in the *Posterior Analytics* and is entitled quite naturally *al-Burhān*, 'the demonstration', the title given to this work by its translators; Chapter 7 of the second part of this book is about the relationships between the sciences: in which way they differ, and on what they have in common.[46] The text, of a very formal structure, is a remarkable work of epistemology.

Thus the sciences can differ because they deal with different subjects but also in dealing with the same subject. In the first case, either their subjects totally differ (e.g. arithmetic and geometry), or they interfere (*maʿa mudākhala*), and then, or (1) one of them is like genus, the other species, or (2) there is between them something in common and something different: thus medicine and morals both study the powers of the human soul in so much as man is an animal, but medicine is devoted to the human body and its members, morals to the thinking soul and its practical powers. Case (1) itself subdivides: either the relationship is that of generality to the particularity, or it is the case of generality of inseparable attributes such as the one, the being. The first subdivision subdivides again, according to whether one of the sciences concentrates on a species and the other on the genre of that species (thus the study of cones in relation to that of solids); or according to whether one studies a genus and the other an accident of a species listed under this genre (relationship of physics to music); or whether the particular object is part of the totality of the general and its study is a *part* of the study of this (e.g. the study of cones in relation to geometry), or whether the particular detaches itself from the general, in the sense that one is not interested in its constitutive difference but in the accidents which accompany this difference – such is the relationship between physics on the one hand and medicine on the other, which is concerned with the human body only inasmuch as whether it is healthy or ill; it is not a part of physics but it is listed *under* it. This relationship of subordination specifies itself in four different ways, according to whether the science listed under the other is related to attributes linked to its subject on account of an essential accident (the case already seen of medicine in relation to physics) or a non-essential accident (the study of spheres in movement is listed under the science of solids, or under geometry), or that it is related to an abstract (*mujarrada*) relationship with respect to which it studies its subject (perspective, having as its object lines referred to vision, is not in geometry but under geometry), or that one of the sciences deals with an accident of one of the species of the object which the other deals with in its generality: thus music is listed under arithmetic, and the science of melodies under music and not under physics, because melodies, although being accidents of a body, are studied in so far as they are a matter of number. Returning to the second subdivision of case (1), the science which deals with general attributes which are the being and the one is not listed under any science, all the particular sciences being listed under it without being parts of it; but it has for parts the study of the principle of all being (which is neither one particular science nor a universal science) and that of the principles of the sciences. From this last point of view there are three sciences that are more general than the others, although they differ as regards their subjects, their principles and their ends: first philosophy, dialectic, sophistic. It remains finally to examine the second branch of the very first alternative; one says then that two sciences which have the same subject may differ, whether because one studies the subject absolutely and the other under a certain relationship (thus physics and medicine, with regard to man whom they have as their common subject), or because each studies the subject under a different relationship (thus physics and astronomy, with regard to the body of the world or of the celestial spheres).

Such are therefore the diverse ways in which the sciences can differ; they can communicate as regards principles, subjects, questions. As regards principles (putting aside the principles which are common to all the sciences, which are not the issue here), this communication may occur on the same level (geometry and arithmetic have in common the same principle according to which two things equal to a third are equal among themselves); or the principle of one is previous to that of the other (geometry and perspective; arithmetic and music); or that which is a principle in one is a question in the other, whether the subjects of these sciences are situated at levels of different generality and particularity, a thing shown in one science being principle for an inferior science or a superior science according to whether one considers the whole in itself or for us; or whether they are situated on the same level but the questions of one of the sciences are posed as principles in the other: several principles of book X of *Elements* by Euclid are shown previously in the arithmetical books of the same work. Two sciences communicate as regards questions when their goal is an attribute of the same subject, and that depends on the fundamental communication, as regards subjects. There are three cases here: one of the subjects is more general and the other more particular (physics and medicine; geometry and the study of cones); each of the two has something particular and something in common with the other (medicine and morals); the subject is the same but taken from two different points of view (the body of the sky and the world, a subject common to astronomy and physics).

This game of divisions, specifically Avicennian, can appear tiresome; moreover it does not provide classifications of the sciences strictly speaking (in fact it prepares the chapter devoted to the transfer of demonstrations from one science to another). But it is essential for us, because it forms the theory of *systematic* relations between the sciences, and in so doing unifies a group of partial networks according to which the sciences are related to each other. These networks are themselves formed by the ontological concepts and relations borrowed from Aristotle: genus and species, accident, general and particular. All in all, Avicenna founded philosophically the classification of the sciences in the very reality that they study; one will particularly notice the important distinction between the relationship of the parts to the whole, and the inferior to the superior, that the sciences support between them; the first is based on their respective levels of universality, the second on the difference between the essential or accidental character of the proper subject of each science in relation to the category of things considered. It is not necessary to reason on the choice of examples; the reader will observe that they pertain to almost all the principal divisions detailed by al-Fārābī – minus the science of language and politics.

*The Epistle on the Parts of Intellectual Sciences* (*Risāla fī aqsām al-ʿulūm al-ʿaqliyya*)[47] presents a systematic table of the sciences. The starting concept is that of philosophy, defined as a 'theoretical art', divided into an 'abstract theoretical part' that lets us acquire certain knowledge concerning beings who do not depend on our action, and a 'practical part' through which we correctly conceive of what it is necessary to do to achieve good. The theoretical part is subdivided into physics, inferior science; mathematics, intermediate science; metaphysics or theology (*al-ʿilm al-ilāhī*), superior science. The practical part is subdivided into three sciences which consider, respectively, the behaviour of one sole person (see the *Ethics* by Aristotle) and the behaviour within a domestic association (see the *Economics*) or within a civil association (see *Politics*, the *Laws*, that

Avicenna relates to Plato but seems to reduce to 'two books' about prophecy and religious law). He deals no longer with this practical part of philosophy; none the less Avicenna subdivides in detail the three theoretical sciences, by distinguishing in each what is the principle and what is a branch (*farʿ*).

1 In physics, the parts of what is principle are eight, each explicitly referred to a book by Aristotle (or which is attributed to him), the object of which is each time briefly summarized; these are *Physics*, *On the Heavens and the World*; *On Coming-to-be and Passing-away*; *Meteorologica I–III*; *Meteorologica IV*; *On Plants*; *Historia Animalium*; *On the Soul – The Sense and the Sensible*; the special parts (*al-aqsām al-farʿiyya*) are seven: medicine, astrology, physiognomy, oniromancy, the science of talismans, theurgy, alchemy.

2 Mathematics (*al-ḥikmat al-riyādiyya*) includes four principal parts – the sciences of number (*ʿilm al-ʿadad*), geometry, astronomy, music – and each one subdivides into special parts: the science of number into Indian calculation and the art of algebra and *al-muqābala*; geometry, into arts of measurement, of industrious techniques, of the traction of heavy weights, of weights and balances, of particular machines, of perspectives and mirrors, of hydraulics; astronomy, into arts of astronomical tables and calendars; music 'has among its branches' the art of the handling of strange instruments such as the organ.

3 Metaphysics includes five principal parts: the study of general concepts common to all beings (identity, unity, plurality, etc.); that of the elements and principles of physics, of mathematics, of logic; the study of the First Truth; that of the 'prime spiritual substances'; that of relationships between the terrestrial and celestial beings, angels, with also what will be called theodicy. Amongst these branches Avicenna cites only two, which are however precisely detailed; these are, in brief, the knowledge relative to revelation and prophecy, and that which concerns future life, the spiritual good and bad.

4 Finally logic, the instrument which allows the acquisition of other sciences, has nine principal parts, revealed in as many of the Aristotelian treatises: *Isagoge*, *Categories*, *On Interpretation*, *Analytics*, *Posterior Analytics* or *Apodictics*, *Topics* or *Dialectics*, *Sophistics*, *Rhetorics*, *Poetics*. Without saying expressly that it does not have secondary parts, Avicenna does not cite any.

In the reading of this summary several observations occur. First, with regard to the general division, as it appears from the beginning of the

*Epistle* and from its plan, one finds there the successive strata of the Greek theories on the subject. The division of philosophy into theoretical and practical appears to be very ancient, and logic is considered sometimes as a part (by Plato, according to Cicero; by the Peripatetics and the Stoics, according to Sextus Empiricus), sometimes as an instrument (Aristotle himself, who distinguishes between the practical and the poietic). In second place, the Aristotelian content in this text is strong: one finds the three theoretical sciences, and this time in their original order; the principal parts of physics, those of logic, are related to as many of the Aristotelian treatises, or considered as such (*On Plants*, *On the World*) or in their orbit (*Isagoge*). Finally, to finish with these Greek references, it is noted that 'mathematical philosophy' takes up the four propaedeutic sciences of the *Republic*, also in their original order, and not Pythagorean. As regards metaphysics, the group of its parts, principal and secondary, corresponds roughly to the plan that Avicenna outlined in the *Shifā'*, I, 4.

If we now consider the secondary parts of physics and mathematics, things are more complicated, and it is only possible here to indicate a few points. It will first be noted that these parts are all practical, but Avicenna calls them, for the most part, sciences; for those of physics, he talks of their goal. Medicine is an exception inasmuch as he divides its goal: knowledge (of body, its states and their causes) and action (to get rid of illness and to preserve health). The fact that the majority of the secondary parts of physics are in our eyes 'false sciences' corresponds to a historical state of knowledge and is not of particular interest here. However, we note two important differences from the classification by al-Fārābī, who said almost nothing about medicine and nothing about strange arts which are for Avicenna secondary parts of physics. We are perhaps authorized to credit al-Fārābī with a more acute critical sense than his successor; and we are certainly forced to note that the latter is less free from the Aristotelian frame. On the other hand the formal principle adopted by Avicenna (the principal, the secondary) allows him to divide up more wisely the sciences which were not included in the antique *quadrivium*: algebra is related to the science of number and no longer simply considered as an ingenious process; optics is better in its place as a branch of geometry than as a science of equal status. As regards what we would place under mechanics and is here only a series of arts, one will not be amazed to see them simply referred to in geometry, science of 'positions' and of 'figures'.

It seems interesting now to compare this effective division to theoretical analyses of the relationships between the sciences such as in the chapter of the *Shifā'* summarized above. We shall not apply ourselves to reconstituting case by case the relationships between predicables which found in principle those of the secondary sciences to the principal sciences. It suffices to consider the sciences which, cited in the two texts, are in addition arranged in couples in the first: it is the only way to pick out sure correspondences. We thus note several cases of certain agreement: the *Epistle* classes as different sciences arithmetic and geometry, whilst the *Shifā'* tells us that their subjects differ totally; according to the two texts medicine is subordinate to physics and perspective to geometry; the fact that physics and astronomy consider the same subject under different relationships (*Shifā'*) explains that they are two different sciences (*Epistle*). In another case the texts seem to contradict each other: in the *Shifā'* physics is put in relation to music which, according to the *Epistle*, is one of the mathematical sciences. The contradiction is only apparent by looking more closely at these things: according to the *Shifā'* the subject of physics is to that of music what a genus is to the accident of a species of this genus; now, still according to the *Shifā'* but in another chapter (I, 1), the mathematical sciences study modes of quantity, which is in another way an accident of the body, which is the subject of physics: it is therefore in the final analysis the Aristotelian classification of the sciences, accepted by Avicenna, which explains this apparent lack of agreement of the latter with himself. It is for a similar reason that the science of melodies is not located under physics: it of course the accidents of a body but inasmuch as they are matter of number, and this double abstraction explains that it is a 'branch' of music but located 'under' arithmetic.

In comparing closely the table of the *Shifā'* and that of the *Epistle*, it appears that Avicenna succeeded in constructing an epistemology so sound as to group into a coherent whole the division of the theoretical sciences just as the *Metaphysics* by Aristotle exposes it, and the organization, originally Platonic, of the *quadrivium*. It is observed, however, that the repartition of the sciences into principal and secondary, in the *Epistle*, does not have the degree of precision which the analyses in the *Shifā'* achieve, because the word 'branch' seems to encompass an image rather than a concept; but it could also be that this imprecise formulation expresses in its way a specific character of the doctrines and learnings of Arabic expression: 'the easing of the traditional opposition between science and art', which, by making the frameworks inherited from Aristotle and Euclid collapse to a certain extent, has allowed for an extension of research and a progress of results, as the works of Rashed have shown.[48]

We have thus summarized and analysed briefly the classifications of the sciences due to the first three of the great *falāsifa*. They call for some supplementary remarks. First we note a paradox: in reading the classification by al-Kindī one could only guess that of these three he is the most authentic scholar, and of great class. His *Epistle* is doxographic and pedagogic – the pedagogy of course of a philosopher, since the propaedeutic role of logic and mathematics is based on the nature of things; but one finds nothing there which announces the conceptualizations of al-Fārābī and Avicenna; one can imagine, however, that one might find such things in the lost works, perhaps in the *Book on the Quiddity of Science*. The second observation is that, all founded as they are on Greek philosophy, two of these classifications have something of the nature of the religious concepts of their authors, notably by explicit references to prophecy; only al-Fārābī keeps a distance which is hardly reduced by his chapter on the *fiqh* and the *kalām*. Finally these treatises – and we take up again and generalize here our first remark – are not science but are a rather schematic reflection on science; nevertheless the last two record in a not very clear way for themselves the underlying movements of the ground.

Conversely, these classifying works will not be judged marginal in relation to the general movement of scientific thinking; the history of the sciences is not only made up of adventures and discoveries, i.e. surprises. The largest part of its life consists in an activity of which we barely catch a rumour. The great classifications of sciences such as those by al-Fārābī, by Ibn Sīnā, attentive as much to what lasts as to what moves, introduce us to two scenes: the one where (still?) obscure scholars pursue a secular effort according to the norms and frameworks which were usual to them, and the one where inspired minds shatter the edifice and force a reconstruction.

## NOTES

1 One still uses the edition by G. Flügel (Leipzig 1871–72); the most complete is the one by R. Tajaddud (Teheran 1391/1971); English translation by B. Dodge *The Fihrist of al-Nadīm*, 2 vols (New York 1970).

2 Edition G. van Vloten, 1895 (reprinted Leiden 1968): *Liber Mafātīh al-Olūm explicans vocabula technica scientiarum tam arabum quam peregrinorum, auctore Abū Abdallah Mohammed ibn Ahmed ibn Jūsof al-Kitāb al-Khowarezmi.*

3 Further on he takes up again the division of the sciences by bringing in the non-religious sciences from the point of view of the legal obligation which is or is not attached; see Gardet and Anawati (1948: 113–21), where one will also find several classifying schemas; Anawati (1976: 61–70); and the plan of several encyclopedias in Peters (1968: 105–18) and Makdisi (1981: ch. 2, I and II).

4 Text in Chejne (1402/1982: 216–51); English translation, *ibid.*, pp. 190–214.

5 See Marquet (1975: 295–313).

6 The most recent French translation of his *Muqaddima* is that by Monteil (1968 and 1978); English translation by Rosenthal (1967b).

7 Flügel: I, 255–61; Tajaddud: 315–20; Dodge: II, 615–22.

8 Two editions: Guidi and Walzer (1940: 375–419) (GW) and Abū Rīda (1369/1950: 363–84) (AR). Al-Kindī touches also in his other treatises on the

question of the classification of the sciences; see Cortabarria-Beitia (1972: 49–76).

9 pp. 364–9 AR; pp. 390–3 and 404–7 GW (the first reference is to the text, the second to the Italian translation). One will note that the science of the soul is detached from physics; this goes back to the school of Athens; see GW, pp. 379–80 and Walzer (1962: 201–2).

10 pp. 369–70 AR; pp. 394 and 407–8 GW. The order of the mathematical sciences is that of the *Republic* by Plato.

11 pp. 370–2 AR; pp. 394–5 and 408–9 GW.

12 pp. 372–6 AR; pp. 395–7 and 409–12 GW.

13 pp. 376–8 AR; pp. 398–9 and 413–14 GW.

14 P. 378 AR; pp. 399 and 414 GW. The situation of the moral works, right at the end of the corpus and just after metaphysics, is unusual: the ancient catalogues of works by Aristotle generally propose more or less different systems (see Moraux 1951: especially pp. 147, 182, 190). Gutas has shown recently that the order followed by al-Kindī is found in the work of Paul of Persia (sixth century) and, in Greek, in the work of his contemporary Elias, and probably also in David; cf. Gutas 1983: 235, 237); but these authors are not definitely the direct, or unique, source of al-Kindī, who gives a place separately to the books on the soul (see above, note 9). One will note that Ibn al-Ṭayyib also places the books on morals after those on metaphysics (*Ibn al-Ṭayyib's Commentary on Porphyry's Eisagoge*, p. 38).

15 pp. 379–84 AR; pp. 399–403 and 414–19 GW. Here *On the Soul* is integrated into the group of books on physics. This is not the place to enquire about this divergence with (1), nor to examine the contents of this last list.

16 See the first part of the *First Philosophy*, pp. 103–4 AR.

17 *First Philosophy*, pp. 102–3 AR; *De aspectibus*, ed. Axel-Björnbo-Vogl, p. 3.

18 *Iḥṣā' al-'ulūm*, ed. Amine, 1968. The work was translated into Latin in the twelfth century by Gerard of Cremona (ed. Gonzales Palencia). It forms the base of *De scientiis* by Dominicus Gundissalinus (ed. Alonso) and makes up a part of the sources of the *De divisione philosophiae* by the same author (ed. Baur). On these points see Hugonnard-Roche (1984: 41, 61–2). The *De ortu scientiarum*, the original of which is lost, was published by Bauemker (1936). On *Enumeration* see Mahdi (1975: 113–47).

19 *Op. cit.*, pp. 53–5.

20 *Ibid.*, pp. 57–66.

21 The integration of *Rhetorics* and *Poetics* into *Organon*, which is noted already in the work of al-Kindī, was at first the doing of Alexandrian commentators: Ammonius, Olympiodorus, and above all Elias, who counts five sorts of syllogisms: apodictic, dialectic, rhetoric, sophistic, poetic; see Moraux (1951: 177–83); Walzer (1962: 133–4); Gutas (1983: 242, 249).

22 *Op. cit.*, pp. 67–91. The phrase which has just been cited in the text takes up again an idea expressed by several Greek commentators: Ammonius, Simplicius, Olympiodorus, Elias; see Moraux (1951: 180) and Gutas (1983: 234, 242).

23 *Op. cit.*, pp. 93–5.

24 *Ibid.*, pp. 95–8.

25 *Ibid.*, pp. 98–102.

26 *Ibid.*, pp. 102–5.
27 *Ibid.*, pp. 105–7.
28 *Ibid.*, pp. 107–8.
29 *Ibid.*, pp. 108–10.
30 *Ibid.*, pp. 111–20.
31 *Ibid.*, pp. 120–3.
32 *Ibid.*, pp. 124–30.
33 *Ibid.*, pp. 130–1.
34 *Ibid.*, pp. 131–2.
35 *Ibid.*, pp. 132–8.
36 *Ibid.*, pp. 57–8.
37 Only two allusions are made: on pp. 57–8, where it is cited amongst other arts, and p. 126, for a comparison of the role of experiment in the formation of physician and politician.
38 Elsewhere al-Fārābī reconstructs a historical development of the 'arts'; at first would have come rhetorics, then poetics, then, language having been set up, one would have come to dialectics and to demonstration, whilst the knowledge of things and politics would have developed by profiting from these arts of the language (*Kitāb al-ḥurūf*, pp. 142–53; see also *Kitāb al-khaṭāba*, in ed. Langhade-Grignaschi pp. 54–7). One sees that this genesis only very partially corresponds to the table proposed in the *Enumeration*.
39 Certainly, his enumeration of the diverse ways of practising the *kalām* is not rash; it stems from the situation of this science in his time, but it remains in the plan of abstract description.
40 *Op. cit.*, p. 128; the explicit mention of the *Politics*, placed in the text in square brackets, is only found in one sole Arabic manuscript and in the Latin translation; see the critical apparatus.
41 See above, as regards al-Kindī. The stereometry that Plato detaches in some way from geometry is here reintegrated, but as a part simply of theoretical geometry; al-Fārābī did not give it special attention in presenting practical geometry.
42 *Op. cit.*, p. 99.
43 See Rashed (1984a: especially ch. 1).
44 *Op. cit.*, p. 109.
45 *Ibid.*
46 Avicennae, *De demonstratione*, ed. Badawi, pp. 106–11. This chapter seemed so important to Gundissalinus that he integrated the translation into his *De divisione philosophiae*, pp. 124–33; see Hugonnard-Roche (1984: 42, 54–7). For the influence of Avicenna on this subject in the Latin West, see Weber (1984: 77–101).
47 'Risāla fi aqsām al-ʿulūm al-ʿaqliyya' *Tisʿ rasāʾil*, pp. 104–18. This text has been the subject of several translations, complete (the first two cited) or partial (the second two): Anawati (1977: 323–35); Mimoune (1984: 143–51) in Jolivet-Rashed (1984); Mahdi (1967, pp. 95–97); Michot (1980).
48 See in particular Rashed (1984b: 29–39).

# *Postface*

## *Approaches to the history of Arabic science*

MUHSIN MAHDI

### PRELIMINARY REMARKS

The present book is devoted to the history of Arabic science. Today, one normally understands science to be modern science, principally 'hard' or 'exact' science and technology, something the Western world possesses and the Arab world covets. The study of Arabic science in the Western world aims at discovering those aspects of Arabic science in which advances were made or which contributed to the rise of modern science; and the study of Arabic science in the Arab world is meant to prepare the way for the appropriation of modern science and technology. In every case, modern science and technology is taken to be the aim of scientific development and the measure by which earlier science is to be judged. History, on the other hand, is thought to be a method used in searching for, collecting, organizing and presenting the Arabic science of the past. Yet history in the manner practised by the authors of this volume is also a modern science that emerged after modern philosophy and science and has undergone various transformations. Its foundations are not always evident and its premises are often not made explicit. Since the contributors to this volume do not go into the question of the *history* of Arabic science as such, it should be useful to reflect on certain aspects of it in this essay.

What, then, is the history of Arabic science – Arabic science and philosophy cannot be separated in the period under discussion without doing violence to each of them; and, generally speaking, 'science' should be understood to include the philosophic sciences in this essay – and how is one to approach it? Why is it that one cannot speak of Arabic science without being concerned with its history in particular? How do the sciences practised by the Arabs become part of the history of science? How are 'history' and 'science' joined together in this volume? In the absence of an adequate historiography of the history of Arabic science, a preliminary typology of approaches may prove useful.

In the Arab world, widespread interest in the history of Arabic science is mainly due to the special status of modern science and the perception that modern science must be acquired if the third world is to modernize itself; the fact that Arabic science existed in the past is meant to prove that the acquisition of modern science is at least possible. In the West, the relative neglect of the history of Arabic science is part of the neglect of the history of science in general. (The attitude toward the history of science prevalent among professional philosophers in Anglo-Saxon countries and on the Continent, and among their disciples in the Arab world, reflects two significant trends in modern Western thought – positivism and historicism – that will be discussed later on in this essay.) As one looks into the practice of departments of history of science, when they exist at all, and departments of philosophy at Anglo-Saxon universities, one gets the impression that none of this history is truly relevant to the study or understanding of modern science and modern philosophy. In the departments of history of science, the study of modern and contemporary science is emphasized. In most departments of philosophy the history of philosophy is hardly ever taught; it is certainly not a respectable discipline. If you want to study science or philosophy, you do science or philosophy; you do not study the history of science or the history of philosophy, which is not science or philosophy. This is one reason why the history of philosophy – and almost all earlier philosophers were also scientists – has been for all practical purposes banished from philosophy departments in the Anglo-Saxon world.

To the extent that interest in the history of science persists in the Anglo-Saxon world and on the Continent, modern science is viewed not merely as a fact of everyday life, a necessary evolution, a successful revolution or a practically useful instrument, but as a human phenomenon that needs to be clarified and understood within a broader human context. And since the broader human context changes through time or according to cultural situations, the history of science can be interesting in itself and not merely useful for the study of modern science. It is not enough to clarify the concept of science, the logic of science or the language of science as understood and used by modern science itself, or even the social and cultural context of modern science. Interest in history in general, and the history of science in particular, is now justified not for its own sake, as antiquarian interest or for learning the lessons of history, but as a means for understanding the social and cultural context of modern science through a comparative study of the social and cultural context of science in earlier times and in other climes.

The modern histories of Arabic science belong to that trend in modern historical studies which turned away from political history and the history of war and peace (e.g. the *History* of Thucydides) or the history of prophets and kings (the well-known *History* of al-Ṭabarī, for example). In part, it continues the historical tradition that reported the histories of illustrious men, the doxographies and biographies of scientists arranged by nations, generations, schools, specialties (e.g. the works of al-Nadīm, Ibn Juljul, Ṣā'id al-Andalusī, al-Qifṭī, and Ibn Abī Uṣaybi'a) and the histories of doctrines and religious sects, such as those by al-Ash'arī and al-Shahrastānī. The purpose of all these histories appears both simple and defensible. Starting with the information supplied by their predecessors, a number of the leading modern historians of Arabic science collected, organized and presented in a vastly improved form information about the biographies and works of Arab scientists. Modern biographical and bibliographical histories – one thinks mainly of the massive works of George Sarton, Carl Brockelmann and Fuat Sezgin, and the identification and description of manuscripts and printed books on which they rely – provided indispensable tools for the historian of Arabic science.

Another type of writing about science practised in the past was not called history by its authors, yet we tend to call it history today. For instance, in a number of dialogues Plato offers a polemical account of the scientific opinions of pre-Socratic philosophers. At the beginning of the *Metaphysics* and elsewhere, Aristotle gives a retrospective account of the opinions of his predecessors and contemporaries about the principles of the beings. And many Arab scientists, e.g. Ibn Khaldūn, begin their own works with an account of the opinions of their predecessors. Although nowadays we call these accounts histories of science, in fact they are accounts of opinions, restated as prolegomena to the statement of the authors' own opinions about, or clarifications or solutions of, the questions they happen to be treating. They engage in dialectical discussions with their predecessors or contemporaries in order to assure themselves and their readers that the positions they are stating or defending have not been stated already, undermined or refuted by an earlier thinker, or that their predecessors were groping for the truth, took the first steps toward it, or prepared the way for it. Modern philosophers and scientists – Hegel or Renan, for instance – followed this method. Although modern historians of Arabic science are not themselves scientists and therefore do not use this method of writing for the same purpose, any account of past scientific opinion that is not merely a paraphrase or a summary involves this method to some degree and defends a certain view of science and its history.

In modern times we have inherited, principally from Germany, two kinds of general histories of science: history of doctrines (*Dogmengeschichte*) and history of ideas (*Ideengeschichte*). Histories of doctrines, many of them still in use today, are essentially classificatory. They present paraphrases and summaries of the contents of the works of earlier scientists, with comments and a certain amount of information about their lives and times, arranged according to periods, countries or disciplines. (In France, this kind of history was represented by Charles Renouvier, *Esquisse d'une classification systématique des doctrines philosophiques* (2 vols; 1885, Paris).) Histories of ideas, on the other hand, are concerned with genetic filiations, indebtedness, impact and influence. (In the United States, this kind of history was represented by Arthur Lovejoy, *The Great Chain of Being* 1936, Cambridge, Mass. and by the *Journal of the History of Ideas*.) One studies the same doctrines, but diachronically, and one divides them in a special way, analyzing and reconstructing them for the purpose of bringing out such hidden things as assumptions, unconscious mental habits and the relation between doctrines and the spirit of the age (*Zeitgeist*).

## ARABIC SCIENCE AND GREEK SCIENCE

The simplest answer to the question – why history? – is that it is important to understand the genesis of scientific theories. Scientists try to solve certain problems. The proper elaboration of the questions raised, seeing the difficulties involved in the problem and the proposed solution, may require successive efforts of thought. This is what great scientists are engaged in. They see their true predecessors, who may not be their immediate teachers, as having presented a solution, and they see a problem with that solution – a contradiction, a confusion, an inconsistency – and they push this effort a step further. In this sense, there is an internal history of science that cannot be neglected without missing something quite significant. Scientists are not self-enclosed monads, each simply pulling things out of a hat – which is the impression one gets from those histories of science that recount what X says and then what Y says. We are in a way dealing with a kind of necessary history. This is why one cannot move scientists about and reorder them at will, e.g. take Averroes and place him before al-Fārābī or take Kant and place him before Plotinus. One has to figure out, slowly and carefully, why this is the case. Is it merely because Averroes was an Andalusian or a judge, or that Kant was a Prussian or a Christian or a European? Or is it something more than that? Is it possible that Averroes's relation to Ibn Bājja and Ibn Ṭufayl is more important than his relation to al-Fārābī and that Kant's relation to Hume is more important than his relation to Plotinus? Is there a kind of connection that cannot be reversed?

In this context, we must also ask a question – why the Greeks? – that was very much on the mind of a number of Arab scientists in medieval times and that continues to bother some Arab thinkers today. Why is it that the very word 'philosophy', as Diogenes Laertius says, refuses to be translated into foreign speech? Why does everyone seem to take it for granted that one must start with the Greeks or go back to the Greeks?

There are some who become nervous for the wrong reason when faced with this question. They think that, historically and culturally, the Greeks belong to them; therefore, if anybody else claims he is following the Greeks or knows something about the Greeks, he is trespassing on their private property. There are others who are constitutionally allergic to the Greeks. They feel that the Greeks are the source of all evil in human life: they were rationalists who flattened life and abandoned concern with its inner mysteries. Therefore, to take a stand for the mysterious, the irrational, the unconscious, necessarily involves, they think, the rejection of the Greeks. And since we are now supposed to be investigating a non-Western culture, those who are attracted to non-Western cultures because they are running away from modern rationalism to the mysterious cannot hear someone say that Arabic science had something to do with the Greeks without experiencing a letdown, a cold shower. There were Arab thinkers who argued against Greek logic or metaphysics. They, too, wondered why so many intelligent persons should be concerned with the Greeks, even after the coming down of a new revelation, the true religion, and so many advances in knowledge and technology, including the sciences. What is so special about the Greeks?

One cannot say that the impact of Greek science on Arabic science came about because there was nothing to work against it. If this impact did happen, and in certain respects Greek science did triumph, it was because there was nothing that could stop it, because any effcrt to understand certain things (including perhaps the human understanding of religion) was of necessity drawn into the problems posed by the Greeks and had to argue these problems in Greek terms, even though these terms had to be modified, or one strand of Greek thought had to be chosen in preference to another – for instance, Plotinus or Proclus or Philiponus rather than Plato or Aristotle. Despite some of our present-day prejudices, we have to consider seriously the proposition that perhaps Greek thought did present what Averroes understood as the natural starting point of all possible human thought. This does not mean that other nations did not create or possess other things – statecraft, technology, drama, music, religion – superior to their Greek counterparts. The question 'why the Greeks?' has to do with scientific thought. The Arab scientists who suggested the proposition I have just stated did not mean that the Greeks had all the solutions, but that the Greeks offered the right framework and possible avenues for pursuing the solution. In order to understand new things (and they knew that there were many new things – religion, to begin with, in this particular form was new, to say nothing of various new arts), they needed to extend, modify, elaborate and sometimes reject older notions and make a fresh start.

In addition, we need to ask how Arab scientists themselves relate their own thought, implicitly or explicitly, to that of earlier thinkers, how they see their own place in that history, and perhaps also how they see themselves in relation to the future – i.e. what they would like to see come about. We shall need to ask about the role of time in their works: whether their own reflections or researches led them to a linear or cyclical view of the movement of science; whether, for instance, they believed in something like progress or regress in scientific thought, or in social and moral life. One part, but only one part, of this inquiry will be to look at the way in which the Arab scientist perceived of the relation between science and disciplines like theology, mysticism, history and politics, and whether he saw science as belonging to a certain phase in the development of social life in general.

In order to do all this properly, we need to distinguish between what can roughly be called the scholarly and the scientific work proper. In modern science the scholarly work and the scientific work have been largely (if never completely) separated. It is not always easy to make this distinction when reading the works of premodern scientists. But where it can be made, it is helpful for understanding a scientist's view of the history of scientific thought, even though in many cases an Arab scientist tends to present his own work in the guise of a history in which he appears to be stating the opinions of earlier thinkers. In this context, we should develop a certain appreciation for the effort of many Arab scientists to recover earlier thought. Nowadays we have libraries with many millions of volumes. Every significant work exists in the original in many editions, in numerous translations and with many commentaries. And tomorrow any piece of information will be available to anyone who can push a few buttons. We may think, then, that the task of recovering almost any scientific work consists of a short walk to a library or of turning on the computer terminal. Let us not forget that this was not always the case. Under certain conditions in the past, the recovery of the writings of even major scientists and philosophers such as Plato, Aristotle, Ptolemy or Euclid, was a task of major proportions. It required public interest and support, a prosperous and leisurely intelligentsia and above all a great deal of time and effort on the part of translators and interpreters. Even more than this, it required a great deal of rethinking and finding ways to relate the thought of earlier times and foreign nations to contemporary conditions, languages and habits of thought.

As we look at the results of the effort of Arab scientists to restate Greek thought, we need to see if it is possible to distinguish between the work of clarifying and re-presenting the thought of earlier thinkers, on the one hand, and the work of modifying and extending the earlier doctrines or points of view. These two kinds of activities usually go hand in hand; this is why it is important as one reads these works to look at the points or junctures where an earlier thought is restated, where the restatement ends and where something new takes place. For reasons that are not always evident, these two things are sometimes combined and the distinction between them is not clearly made. The situation would be simple if an Arab scientist were always in the habit of saying, 'This is what Aristotle said and this is what I say.' Somehow, it all usually goes into either 'what Aristotle said' or 'what I say', and we ourselves have to do the work of distinguishing between the two.

## SOURCE CRITICISM

If one were to ask in what direction and how far back one needs to go in order to understand the genesis of a scientific concept or premise used by an Arab scientist – whether, for example, one can be satisfied with the immediate source or whether one needs to go to the ultimate source – the answer will obviously depend on the concept or premise in question. It is not enough to say that Arabic science depends on translations or reports of earlier thought: one needs to follow the concepts and premises as far back as practically possible, using available indications of sources. For instance, in the first chapter of the most recent history of Islamic philosophy (Majid Fakhry, *A History of Islamic Philosophy*, 1970, New York), the author suggests that one must begin the study of Islamic philosophy by becoming acquainted with the so-called *Theology of Aristotle* and the so-called *Liber de Causis*, of which he gives a paraphrase for that purpose. It is of course impossible to understand the *Theology of Aristotle* and the *Liber de Causis* without going back to the *Enneads* of Plotinus and the *Elements of Theology* of Proclus. The former are not mere translations or extracts from the latter, but are already new versions in which the earlier works have been modified in a number of significant ways. One cannot see what has been modified – and therefore cannot ask the crucial question as to why – unless one compares the later works with the works from which they were derived. And one cannot stop there; one meets a similar problem with *The Elements of Theology* and the *Enneads*; Hellenistic science, too, is dependent on earlier scientific thought. Plotinus invariably presents his thought in the following manner. The great masters, he would say, are Plato and Aristotle. This is Plato's position; this is Aristotle's position; these are the positions of the Stoics and others; this is the state of the question; and this is how I formulate or solve it. So, again, you do not have a proper starting point;

one has to go back to what al-Fārābī calls the 'two sources' of all philosophy.

A second example will perhaps illustrate better the difficulties involved in certain strands in the current historical approach to source criticism (*Quellenforschung*). A scholar who made significant contributions to clarifying certain aspects in the early history of Arabic science and philosophy (Richard Walzer, *Greek into Arabic*, 1962, Cambridge, Mass., p. 31) states that al-Fārābī's *The Philosophy of Plato* is of great importance 'although it does not reproduce the Greek original in full and omits the ideal doctrine and the immortality of the soul'. But nowhere is it shown how one knows that the presumed Greek original was fuller than what al-Fārābī presents. Nor is it specified whether the presumed Greek original contained the 'ideal doctrine' and the 'immortality of the soul', which al-Fārābī then omitted, either inadvertently or deliberately. Yet the statement asserts that the presumed Greek original did contain the 'ideal doctrine' and the 'immortality of the soul' and that for some reason al-Fārābī omitted them. Now, regardless of the question of the relationship between al-Fārābī's account and the presumed Greek original, it is a fact that al-Fārābī's account omits these two topics from an exposition of Plato's philosophy in which he says explicitly that it is an exposition which is meant to be complete. The question is: what does this omission mean? It is useful to consider what al-Fārābī says about Plato elsewhere.

In *The Harmonization of the Opinions of Plato and Aristotle*, we see that al-Fārābī was very much aware of Plato's 'ideal doctrine' and Plato's view of the 'immortality of the soul' as these doctrines are presented in well-known places in Plato's dialogues. Of course, we can state this fact, too, and yet fail to understand it or relate it to the first fact – i.e. the omission of the two doctrines in question from the account of Plato's philosophy in *The Philosophy of Plato*. But if we try to see the relationship between the statements about these doctrines in the second work and their omission from the first, we must come to the conclusion that the omission from the first was deliberate, and that al-Fārābī did not omit these two doctrines merely because he did not know that Plato spoke about them, or that they are important, or that tradition had considered them characteristically Platonic. However, this is not enough. In order to reach a more conclusive judgment as to which of the two works is meant by al-Fārābī to represent Plato's genuine doctrines or his philosophy proper, we must try to find out whether these two works by al-Fārābī are meant to present the same thing – i.e. the philosophy of Plato. At this point, we notice that in the *Harmonization* al-Fārābī says he plans to give an account of Plato's 'opinions' (*ārā'*), not an account of his 'philosophy' (*falsafa*). We find, further, that this work is throughout much more rhetorical in style and purpose. In *The*

*Philosophy of Plato*, on the other hand, al-Fārābī is quite insistent on presenting Plato's 'philosophy', the whole of it, and every part of it. The conclusion seems to be this. Al-Fārābī did not consider the 'ideal doctrine' and the 'immortality of the soul' to be parts of Plato's 'philosophy', but to belong to Plato's 'opinions.'

This conclusion does not contradict any hypothesis we may have regarding the presumed Greek original. One may assume that these doctrines were not in the Greek original, and al-Fārābī, satisfied that they were not necessary for an account of Plato's philosophy, did not add them. Or, they did exist and al-Fārābī omitted them because he did not think they belonged to an account of Plato's philosophy as distinguished from an account of his opinions.

To say that al-Fārābī refused to accept the 'ideal doctrine' and the 'immortality of the soul' as belonging to Plato's philosophy proper is, as it were, a new fact, which, again, needs to be understood. We need to learn how al-Fārābī read Plato – whether the Platonic writings themselves or summaries or accounts of them. That is, we need to find out how he understood Plato and how he interpreted Plato. It is also useful to remember how other great philosophers read, understood and interpreted Plato. Aristotle, for instance, seems to have taken Plato's 'ideal doctrine' seriously and tried to refute it, and since Aristotle did not seem to believe in the immortality of the soul, one might conclude that al-Fārābī was trying to understand Plato or interpret Plato in an Aristotelian manner. But this view would be hard to defend because al-Fārābī as well as his readers knew that Aristotle had stated Plato's 'ideal doctrine' and criticized it: al-Fārābī could not have been trying to hide something that people did not know anything about. Again, we may come to the conclusion that al-Fārābī thought that Aristotle was restating or giving an account of what Plato had said, or of Plato's opinions, rather than of Plato's philosophy (Aristotle often attributes such doctrines to Socrates, or some other participant in a Platonic dialogue or to the Platonists, mentioning them by name and referring to those who hold the doctrine of the ideas as a group).

Another way to understand the significance of what al-Fārābī does is to consider the omission in relation to the doctrines of the revealed religions, and especially to Islamic doctrines. Now it is clear that the doctrine of the 'immortality of the soul' in some fashion is basic to Islamic belief. Al-Fārābī's deliberate omission of this doctrine from Plato's philosophy does not seem to be necessitated by the effort to harmonize the doctrines of the philosophers either with religious doctrines in general or the doctrines of a particular religious group or sect with which he may be said to be connected. On the contrary, it would have been more useful for this purpose if he had stated Plato's doctrine of the 'immortality of the soul' and even perhaps his 'ideal doctrine', which is close to certain theological views about God's attributes. Thus one way to understand al-Fārābī's omission is to say that, according to al-Fārābī, these doctrines were not part of Plato's philosophy, but opinions he held to express his agreement with generally accepted views, the pre-Islamic versions of the Islamic religious views. Al-Fārābī seems to be sharpening the contrast, if not the conflict, that exists between genuine philosophy and generally accepted opinions. The main purpose of these remarks, however, is to show that it is not sufficient to state the fact of an omission and then assume that it was due to historical accident, to some presumed lost Greek original, or to oversight. Statements of fact, such as the fact of an omission, further our understanding only if we make them the starting point of further reflection rather than just holding them up as confirmation of general hypotheses regarding presumed historical dependence.

## POSITIVISM AND HISTORICISM

The history of science and philosophy as we know it today is a post-Hegelian phenomenon. In general, it assumes the *completion* of philosophy and the attainment of wisdom (which has been the aim of philosophy since the beginning), by positivism, or Hegel, or historicism, or scientism. All earlier attempts to seek wisdom are viewed through this realized wisdom, i.e. as 'relevant' or 'irrelevant' to this end, each relevant attempt presenting an aspect or stage that was eventually integrated in the final synthesis; or else it is thought that wisdom has been achieved through a new discovery or insight, e.g. cultural relativism, and all earlier science is therefore essentially irrelevant. One must start with the conviction that wisdom is no longer an object of enquiry. But, what if wisdom has not, in fact, been attained by those who have claimed to achieve it in modern times? Or, what if complete wisdom is not possible for humans? What if science is a continuous search for or the love of wisdom? What if love of and search for wisdom is all that a human being is capable of? In that case, both what science is and the nature and use of its history have to be articulated somewhat differently. Finally, every history of science must somehow account for the place of the revealed religions in that history. Hegel integrated the revealed religions into a history of *philosophy* that culminates in atheistic secularism. Whether the revealed religions can be integrated into philosophy or remain an alternative to philosophy has been and continues to be an unresolved question.

In addition to scientists, there are classicists, medievalists and Islamists who are interested in the history of Arabic science. Their approach to it, unlike that of the 'hard' scientist, is to suspend judgement about certain assumptions of modern science as to what makes for real science and what remains outside the perspective of science. For historical reasons and due to administrative arrangements, these two approaches tend to correspond to the division between the social sciences and the humanities in our universities, and humanists tend to be identified as those who show greater interest in such things as philological competence, broader understanding of the setting or context of Arabic science, and the use of certain indispensable tools of historical scholarship. What is at issue, however, is something else. It is the difference between two theoretical positions regarding what constitutes science or knowledge. Although each consists of a number of strands and the two often overlap, they can be distinguished as positivism and historicism, respectively.

For positivism, the only possible objects of scientific enquiry are facts and relations among facts. The aim of science is to describe and predict so as to ameliorate the human condition: 'Science whence comes prediction; prediction whence comes action', said Auguste Comte. This science is seen as the last stage in the general progress of mankind whose history has been dominated by a progressive evolution that has been universal, unilinear, continuous and necessary. Mathematics and astronomy take pride of place in the classification of the sciences. One need only consider this background to understand the heavy emphasis on the applied mathematical sciences such as astronomy and astrology, determining the times of prayer and the direction of Mecca, and similar subjects, among the students of the history of Arabic science; for it is here that the positivist's concern with description, empirical verifiability, prediction and action, reveals itself.

Beyond this, the modern distinction between science proper – so-called 'hard' or 'exact' science – and the history of science is a consequence of the distinction between science and what is not science, causal science and normative science, empirical science and non-empirical science, science and metaphysics. If one accepts what Aristotle or Averroes called science as truly scientific, one will have to study it as one studies the latest scientific theories – i.e. confront it and try to understand and criticize its claim to be an explanation of nature and experience. In general, the distinction between science and the history of science does not exclude the possibility that earlier scientific theory may have contained a nucleus of truth or contributed to some degree to the emergence of modern or contemporary science. It is, in fact, generally assumed that this was the case; one tries to ascertain to what extent and in what sense Arabic science contributes to modern or contemporary science. This is done on the basis of yet another assumption: that present-day scientific theory (and present-day science in general) is the unquestionable, final standard against which the achievement of earlier science is to be measured. This assumption is also behind the use of current concepts in the interpretation and evaluation of earlier science, without always asking whether they are meaningful in this context. It is assumed that these concepts will help transform a subject matter which in itself is not scientific or is only partially scientific into the subject matter of a more rigorous science. Thus premodern science, which is thought to have been unhistorical, becomes a legitimate scientific enterprise when it is approached historically in this manner. What contemporary science would like to see is a truly scientific history of scientific theory taking its bearing from the premise that scientific knowledge is possible only about facts and relations between facts, and that everything else, such as 'values', should be studied as facts and related to other facts which can then include on an equal plane the history of scientific institutions, scientific myths and scientific madness (the psychopathological history of scientists in earlier societies).

Historicism emerged out of the distinction between the methods of the natural sciences – 'naturalism' – and the historical sciences as fundamentally different ways of looking at the world. The historical sciences accept the premise that all science is caught up in a process of change. The nature and value of anything is to be assessed by determining its place within a process of development – (hence the genetic model of explanation) – and its place within the larger process or whole of which it is a part (hence the social or cultural context model of explanation). In principle, historicism considers modern science, like premodern science (including Arabic science) to be just another historical event relative to the spirit of its time, developing out of and anchored in certain conditions and cultural contexts. Modern science has no better or worse claim to being scientific or truly theoretical than any earlier science. The distinction between what is scientific and what is prescientific, or between science and philosophy, loses its importance and the distinction between 'theory' and 'history' is no longer tenable. All science is historical, even though most of it is past history and some of it contemporary or current history. Finally, the distinction between facts and values, which is the hallmark of positivism, is considered ultimately untenable. It may be useful in the study of certain limited aspects of historical phenomena. But the reasons for making the distinction are rejected. Most facts cannot be understood without the judgements of value with which they are charged, as it were. It is not true that only facts as facts can be known; values as values can be known as well as, if not much better than, facts. One cannot dispense with understanding values as values in the study of society; there cannot be a thoroughly factual study of society; and science is just one aspect of a society's world view. Even if it were possible to conduct a merely factual study of science, it would be extremely limited, if not trivial; and it would miss things that are absolutely essential for understanding science and the society of which it is a product. True knowledge of society and science cannot be attained by positivism, but by the science of history or by historical understanding.

In a more positive vein, historicism rejects the distinction between facts and values because it believes that both depend on a comprehensive view or a world view (a *Weltanschauung*) that changes from one society to another and from one period to another. By limiting itself to the study of facts and relations between facts, positivism sticks to part of the surface, as it were, and is not able to penetrate to the origin of these manifestations, which can be properly understood only as manifestations of the comprehensive view that underlies them. These manifestations include values, what people think or believe to be good or true or beautiful, and the articulation of these thoughts in science and art. Values are infinitely more important than facts because they are closer to and express more directly the comprehensive view, the ultimate ground of the culture or civilization or the time. Finally – and this is the crucial initial difference between the positivist and historicist approaches – historicism is based on the premise that values and philosophies and comprehensive views can be known, and can be known scientifically. The only properly scientific knowledge of every aspect of the past and the present, including the scientific knowledge of such things as positivism and contemporary science, hinges on understanding the manifestations of human thought and life in relation to the comprehensive views on which they are based. Modern science, including modern social science, is not the truth and cannot serve as the standard to judge the science of other periods and societies. Like them, it is relative to a particular comprehensive view. The only comprehensive science is the science of history or historical understanding.

Like positivism, historicism tries to solve the difficulty that emerged in the study of man and society as a result of the emancipation of the natural sciences from philosophy and the enormous success of philosophically neutral physics and chemistry. Philosophy is now seen as a sad spectacle of different and incompatible doctrines and schools. There is no hope of resolving these differences or reaching the kind of agreement regarding assumptions, methods, and aims, which is the basis of the program and achievements of modern science. Positivism resolves this difficulty by means of a science of man and society that is philosophically neutral regarding values or judgements of value, the things about which people have disagreed and will continue to disagree. Facts, on the other hand, are thought to be things about which people could agree regardless of their judgments of value. The historicist solution of the same difficulty is theoretically more consistent and radical for two reasons. First, it refuses to sacrifice values and believes that it is possible to develop a philosophically neutral science of the entire range of the human and social phenomena, including judgements of value. Second, it realizes that the hope for agreement regarding facts is illusory: one needs a science that recognizes the fact of unresolvable disagreement regarding facts as well. As regards judgements of value, this science will overcome disagreements regarding them not by asserting that they cannot be understood as judgments of value but by a peculiar understanding of these judgments of value: by understanding them as relative to comprehensive views and by understanding that these comprehensive views change and differ from one period to another or one culture to another. Greeks, Arabs and Indians did, in fact, disagree regarding what is true or valid. The new historical science will understand the outlook of each group and show that it is relative to a Greek, Arab or Indian world-view, respectively. It will be a single historical science that will enable Greeks, Arabs and Indians to reach equally reliable conclusions, on which they are expected to agree. One may have to make allowances for the weakness of the flesh, the persistence of prescientific prejudices and the possibility of skewing the evidence to serve mundane or sacred purposes. In principle, however, neutral historical knowledge is possible. Deviation from it provides fresh material for further neutral historical studies.

## HISTORICAL UNDERSTANDING I

Historical understanding in this sense means understanding all science as relative to something else which in turn pertains to a specific time or society or people. This something may be more concrete than science (such as economic conditions or the political setting) or more general than science (such as the spirit of the time or a particular world-view). In any case, it is not the truth about the nature of man as man or of thinking, but a situation or condition which is historical: it is peculiar to a particular time and place, and has a proper name – Greek, Arabic or Indian. All science is therefore 'true', but true for their setting, and therefore acquire the proper names of their setting. To understand the truth of a particular science requires understanding its setting and its relation to its setting. This historical understanding will show that scientific disagreements, which had seemed unintelligible and arbitrary to positivism, are intelligible and necessary. Their intelligibility and necessity reveal themselves only to historical understanding because it is a historical intelligibility and necessity. All human thought – and this means *all* scientific thought and the very highest principles of theory and practice in science – is relative to specific historical settings. All thought is historical. All truth is historical. The only thought, the only truth, which is not historical, or historically conditioned or relative to a specific historical setting, is the thought that all thought is historical. This encompasses, explains and reveals the truth of all other thought. It is relative to man as man, to the human condition as such, irrespective of place and time. Historicism thus becomes truly scientific: a science of history in which science, philosophy and history are fused.

The implications of this science of history for the study of the history of science are far-reaching. Premodern (Greek and Arabic) science was the quest of knowledge of all the beings and their principles. It was based on the premise that, in principle, such knowledge is possible. Historicism denies this premise. Science is possible and even necessary, but it is essentially the product or a manifestation (in the form of self-consciousness, ideas and ideals, as well as practical needs) of a specific historical setting, which in one way or another led the scientists to think or believe that their thought, which could not in fact have been about *the* beings or *the* principles of the beings, was about *the* beings and their principles. To understand what this science is really about and see that it is not about *the* beings and their principles, one must engage in historical enquiry. In each case, the historical evidence will prove the historicist contention that the scientific ideas and ideals in question were relative to a specific historical setting. And this, as we have said, applies to all science, past, present, as well as future. Not only was science in its original sense impossible in the past; it is equally impossible today. The student of science must abandon the quest for scientific theory and the application of his own scientific theory to the past. The only scientific theory that is legitimate is a theory about the *history* of science that proceeds from the premise that all scientific theories are relative to their settings.

The difficulty, however, is this. The premise of historicism cannot be proved historically or by historical evidence. Historical evidence may show in every case the relation between a particular scientific theory and whatever its historical setting is considered to be. Even if this is shown conclusively, it may prove nothing more than that this particular scientific theory was the product of its setting or that the particular scientist was very much concerned with solving a particular practical problem under the specific conditions prevalent in a particular time and place. It does not necessarily prove that *all* science is relative to its setting. To prove that a single scientific theory is relative to a specific historical setting is difficult enough. There is absolutely no way in which historical enquiry, no matter how extensive or thorough, can prove that all thought is relative to specific settings. At best historical evidence can show that in this or that case a scientific theory can be shown with some semblance of truth to be relative to a specific setting. But this is by no means sufficient to prove the case for historicism.

To do this, one will have to prove that all scientific thought, past, present and future, is relative to specific historical settings. Historical enquiry cannot do this or come anywhere close to doing it. As students of premodern science, we must therefore realize that the fundamental premise on which all this research into the history of science is based is neither self-evident nor demonstrated, and that it cannot be demonstrated by the specialized historical enquiries that are based on it. We must also be aware that, for the most part, these historical inquiries are not especially interested in the historical understanding of science; their primary interest is in the sociology of the time in which a particular scientist or group of scientists lived. This kind of sociology is at best a carefully produced hypothetical construct that changes from one decade to another. And the presumed relation between the thought of a scientist and the hypothetical historical setting is at best educated guesswork. This may seem a relatively simplistic way to state the case against historicism, yet I believe it is adequate to cope with almost all the products of historical studies which are based on it.

## HISTORICAL UNDERSTANDING II

Positivism and historicism have many things in common. Both are essentially modern, the stepchildren of the distinction between philosophy and the peculiarly modern view of science, and the offspring of the belief in progress and the absolute superiority of modern science and scientific history over all earlier thought. Whatever the range of their interest in the history of science or the labor they expend on it, they share the general modern contempt for the past, especially for earlier thought or understanding, for whatever had claimed to be scientific. Even the proposition that one must first understand earlier thought as its authors meant it to be understood, or that one must understand earlier scientists as they understood themselves, rather than measure them by the standards of one's own thought and time, is accepted and applied freely to the way earlier thinkers understood their past (for instance, to the way Arab scientists understood the Greeks, or Enlightenment or Romantic thinkers understood the Arabs), but never to the way positivism and historicism understand earlier thought.

The contempt for the thought of the past robs us of any incentive to study it, unless it is first transformed into something that serves to confirm us in the truth and finality of our own wisdom. As a result, we have effectively broken the bond that ties us to our past, reshaped it in our own image, and ceased to learn from it. We keep producing historical studies that only confirm our belief that the thought of the past is unimportant in itself, that the history of science is theoretically trivial and uninteresting, and that a serious and creative man of theory need not waste his time on a careful study of past science or expend the effort required to understand the thought of even the greatest earlier scientists as they meant their thought to be understood.

The history of science becomes important and indispensable only if we have reason to doubt that the fundamental premises of modern thought in general, and positivism and historicism in particular, represent the pinnacle of wisdom; that they are the final standard by which to judge all earlier thought and all the thought of other societies; that understanding and the quest for knowledge, the original meaning of science, have come to an end as far as the fundamental premises are concerned; that in principle we now possess that knowledge; and that all that remains has the character of a mopping-up operation or of mere application of proven principles to new data. If we do not doubt any of these things, then we have no reason to be seriously concerned with earlier thought or to complain about the unintelligent and uninspired way in which it is being studied. If, on the other hand, we have reason to doubt that the premises of positivism and historicism are self-evident or demonstrable, or that the claim of modern social science and historical science as the final and true knowledge is established beyond a shadow of doubt, then we must rethink the question of the history of science. If, unlike the positivists and historicists, we are not already in possession of knowledge of all the fundamental issues of human thought, science and philosophy, but only seeking for such knowledge, we must ask whether the history of science is of any use to *us* in this search, and if so how it ought to be approached so as to help *us* as we pursue the search.

In order to do so, we must realize that the history of Arabic science is an impossibility if there are no permanent issues addressed by science, if the fundamental questions or riddles of science are historically relative, or if every age or society lives and moves within a horizon that is fundamentally unique. For in that case science itself would be impossible or absurd; and there cannot be a scientific history of this absurdity. The scientific history of such absurdities as alchemy and astrology presuppose sciences like chemistry or astronomy or psychology, which are not absurd. Science deals with man's ability to know, with what characterizes him and distinguishes him from other beings. To say that this is absurd is to say that the whole of man's life is absurd, defies understanding or is ultimately unintelligible. If this were the case, the scientific historian would have to step outside the whole of man's life and, therefore, outside the whole of human science.

In any case, we need not be dogmatic about this. Let us assume an indeterminate relation between science and history or the period or background that is not science. Let us keep in mind that we need to understand also the scientist's own understanding of this history. But let us above all be open to the possibility that understanding the relation between science on the one hand, and the historical setting on the other, requires that we understand science, not as ideology or superstructure, but as science. We must give earlier science the same benefit of doubt that we give current science. Simply to assume a historical setting and to proceed rapidly to explain premodern science as causally related to it or as its product, will not take us very far, just as to do this with current science would be unproductive.

We live in times and in societies whose character is largely determined by science, and in which the most important opinions, the ones that form the foundation of social life and dominate its course, are scientific in origin. Significant social and political changes are created by science, and serious social and political problems are solved by science. At a time and in societies for which science is of such great importance, in which science has made such a great impact, and whose origin and development is inconceivable without science, it seems natural to ask questions about the position of science in all ages and societies. What we do not always realize, of course, is that ours is a new situation in which social and political opinions owe their origins, orientation and force to a specific kind of heritage or tradition, that of science.

To clarify and understand our incomplete, fragmentary and incoherent opinions, we must penetrate to their origins and uncover their grounds or roots. There is no better way to do this than to turn to scientists who developed and presented them in a coherent manner. Modern science, unlike earlier science, must engage in the study of earlier science, not merely to learn something about its ancestry, but also to clarify and understand the foundation of contemporary scientific and social opinions. In this sense, the history of science must become a component of the quest for the foundation of science in a way that was not necessary in earlier times. And from this point of view, too, there is a close analogy between modern science and Arabic science. We moderns, too, do not create our basic notions, but develop them as a result of a critique of earlier notions, Greek, Arabic, medieval Western, early modern; and it is important for our self-understanding to know what was modified, rejected or kept. In this respect, the history of Arabic science may throw some light on the general process of appropriating, adapting and criticizing earlier scientific theories. (The study of Arabic science is relevant for us from yet another point of view. Our current attitude to science is no longer unambiguous. We may not believe that modern science, and the philosophy from which it emerged or which provides its background, can be dangerous for our souls, but we most certainly realize now that it can be dangerous to our bodily existence, to the survival of the human race, and perhaps even to the survival of life on earth. This is a problem we need to understand. The medieval venture in general, and the Arabic–Islamic venture with which we are concerned in particular, provides an example of how such fears about the end of our world arise and how they are met.) In general, we cannot understand the nature of either medieval Arabic or early modern Western science without taking their genesis and respective contexts into account. Similarly, we cannot understand the current situation in the Arab world or in the West and do something about it intellectually without seeing how it emerged and unfolded out of the parent situation or situations. Otherwise, we do not know whether modern science is, as it claims, the final revelation of the truth or only a restricted horizon. And we cannot see this horizon unless we go beyond it and understand its genesis.

The only danger is that we may be charmed by this historical study to believe that, in addition to clarifying our opinions, it will solve our problem, which is the problem of modern science and its relation to society. But this problem is so vast and difficult that we need all the help we can get, and we are helpless unless we first reconcile ourselves to the fact that our progress, inventiveness and achievement do not give a clear and coherent account of themselves. They are grounded in thoughts that deserve to be uncovered and studied carefully and conscientiously. Because of their forward-looking, future-directed character, they either turn us away from this necessary task or else predetermine the outcome of our historical studies so as to whitewash our opinions instead of clarifying their foundation. This is why the question of how to approach the history of science becomes a serious business. For the more history becomes 'scientific', imbued with belief in progress, enlightenment and being on top of the world, and cocksure of its premises and method, the more the blunders, the absurdities and the incompetence in what claims to be understanding, interpretation and criticism of earlier science. We need to find a way out of this vicious circle.

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# 1. Index of proper names


Aaboe, A. 538
Aaron the Priest 909, 918
Abbasids 20, 47, 193, 753
ʿAbd Allāh 246
ʿAbd al-Ḥāmid 370
ʿAbd al-Qādir al-Nuʿaymī 958
ʿAbd al-Raḥmān b. ʿĪsā Muḥammad 258
ʿAbd al-Raḥmān I 244, 248
ʿAbd al-Raḥmān II 248–9, 252
ʿAbd al-Raḥmān III al-Nāṣir 246–7, 251, 920
ʿAbd al-Razzāq 1004
Abdīshūʿ bar Brīka 856
al-Abharī, Athīr al-Dīn 369
Aboaly 973
Abraham b. Dāwūd (Avendauth) 542, 561, 571
Abraham b. Ezra 253, 267; Isaac 267, 278, 282, 287
Abraham bar Ḥiyya (Savasorda) 277, 280, 492–3, 563
Abū al-ʿAbbās al-Nabātī 264, 271–2, 819
Abū Bakr 563
Abū Bakr al-Ḥasan 560
Abū al-Barakāt al-Baghdādī 267–8
Abū Dulaf, Misʿar 802
Abū al-Fidāʾ 809
Abū al-Iṣbaʿ 873–4
Abū ʿItāb ʿAbdallāh 928
Abū al-Jūd b. al-Layth 360, 373, 402–3, 405–6, 417
Abū Kāmil xii, 353–5, 359, 370–1, 394–9, 416–17, 563–70, 572, 578–9
Abū al-Khayr 261, 846
Abū Manṣūr 568
Abū Maʿshar 249, 285, 989
Abū Naṣr: *see* Ibn ʿIrāq
Abū Rīda 707, 1023–4
Abū Ṣāliḥ al-Manṣūr b. Isḥāq (governor of Rayy) 915, 937, 943
Abū al-Ṣalt of Denia 263, 265, 984
Abū al-Ṣaqr b. Bulbul 22
Abū al-ʿUqūl 179
Abū al-Wafāʾ: *see* al-Būzjānī
Abū Yūsuf (Marinid Sultan) 271
Abū Yūsuf Yaʿqūb al-Manṣūr (Almohad ruler) 939
Abū Zakariyyāʾ b. Hudhayl 270
Abulcasis (Albucasis): *see* al-Zahrāwī
Adam 862
Adam of Bremen 886, 897
Adams, O.S. 194–5
Adelard of Bath 21, 252, 285, 287, 541–2, 552–3, 574, 725, 888
ʿAḍud al-Dawla 372, 759–60, 783, 914, 917, 934, 992–3, 998
al-Afḍal (Fatimid vizier) 1002
Afflacius, Iohannes 539
Afghanistan 51, 147, 190, 335, 761–3, 784
Africa 200, 203–4; Central 191; North 244, 566, 756, 759, 762, 765, 783–4, 806, 903; Northwest 133
Agathodaimon 858–61
Aghānīs 464
d'Aguillon, F. 480
al-Aḥdab 387
Ahmad, M.M. 578
Aḥmad (Prince) 669
Aḥwāz 917
al-Aḥwāzī 355
al-Akfānī, Muḥammad b. Ibrāhīm 933
al-Akhawayn 59–60, 63, 76
al-Akhlāṭī, Fakhr al-Dīn 1003
al-Akhmīmī, ʿUthmān b. Suwayd 900
ʿAlam al-Dīn Qayṣar al-Ḥanafī 469
Albert of Saxony 555, 557
Albert the Great 294, 554–5, 575, 726, 728, 891–3, 896
Alcuin 569
Aleppo xii, 167, 179, 282, 914, 940, 990, 999
Alexander of Aphrodisias 445, 644, 669, 677, 706, 710
Alexander of Tralles 978
Alexander of Villa Dei 543, 547–8
Alexander the Great 907
Alexandria 785, 799, 858–9, 862–4, 876, 904, 907, 909–10, 918, 921, 942, 986
Alfanus of Salerno 539, 965
Alfonso 455, 470–1, 493

Alfonso X 244, 246, 255–6, 261, 266, 269, 297, 305
Alfred of Sareshel 876
Alfred the Englishman 895
Algeria 155
ʿAlī 587
ʿAlī b. ʿĪsā 713–14, 948, 950, 983
ʿAlī b. Muḥammad b. Saʿd 261
Ali, J. 157
ʿAllān b. Ḥasan al-Shuʿūbī 987
Allard, A. 415, 570–3, 577
Almohads 263
Almoravids 263, 876
Alonso, M. 264, 1024
Alpago, Andrea 979–80; Paolo 980
d'Alverny, M.-Th. 571, 722
Amari, M. 820, 851
Amico, Giovanni Battista 303, 305
Amida 908
Amīr al-Ḥasan 763
ʿAmmār b. ʿAlī al-Mawṣilī 949
Ammonius 1024
al-ʿAmūlī 610
Anawati, G.C. 709–10, 884, 900, 1023
Anaxagoras 854, 870
Anaximander 870
Anaximenes 870
Anbouba, A. 400, 416–17
al-Andalus 83, 86, 754; Andalusia xii, 15, 17, 18, 21, 130, 150–1, 163, 165, 171, 210, 243–73, 766, 816, 832, 846, 872, 925, 1005
ʿAnkabūthā 811
al-Anṣārī, Abū al-Qāsim Muḥammad b. ʿAbdallāh 874
al-Anṣārī, Abū Zayd 814
Anthemius of Tralles 644, 652, 654–6, 660
Antioch 907, 927, 986, 999
Antyllus 942, 945
al-Anṭākī 409–10, 571
Apian 415
Apollonius of Perga 4, 6, 61, 104–5, 110, 112–13, 448, 472–3, 476, 478, 486–8
Apollonius of Tyana 799, 817, 850, 858–9, 861, 872, 883, 890, 894, 896
Arabia (Arabian Peninsula) 2, 131–2, 135, 155, 204, 756, 765, 799, 806, 810, 811, 827–8, 865, 908, 928
Arafat, W. 670
Aras 861–2
Aratos 860
Archelaos 854, 861, 870
Archibald, R.C. 576
Archimedes 341, 354, 360, 371–2, 419–21, 425, 427, 441, 445, 448–51, 453, 455–6, 464, 472–3, 486, 490–1, 531, 555–7, 559–60, 573, 576–7, 615–19, 623, 626, 630–1, 638, 642, 645, 653, 655, 660, 771, 790
Archytas 451
ʿArīb b. Saʿīd 250–2
Arié, R. 275
Aristarchus of Samos 7, 19, 55
Aristippus, Henry 876, 895
Aristotle 3, 7, 86, 262, 264, 266, 268, 279, 294–5, 305, 431–2, 445, 463–4, 467–8, 471, 573, 615, 617–18, 621, 642, 644, 646, 676–80, 684, 704–7, 710, 718, 721–4, 726–9, 813, 817–18, 855, 861, 869, 872, 876, 885, 892, 895–7, 901, 913, 967–8, 973, 976–8, 986, 1009–12, 1014–17, 1019–22, 1024, 1030–2, 1034, 1036
Aristoxenus 585
Arkoun, M. 1007
Armengaudus, B. 975, 984
Armenia 755, 802, 803, 806, 834
Arnald of Villanova 274, 966, 973–5, 978, 982–3
Arnold of Saxony 892–3, 899
Arrighi, G. 576, 578, 580
Arrowsmith, A. 197
Artephius 860–1, 893, 900
Āryabhaṭa 8, 52, 449
Asclepiades 856
Asclepius 855, 860, 898
al-Aṣfahānī 367, 375
al-Ashʿarī 1028
al-Ashraf (Sultan) 179
Asia 189, 776, 782; Central Asia xii, 130, 134, 147, 153, 176, 190–1, 194, 797, 802, 804–5, 914, 921, 946, 999
Aṣīl al-Dīn 14
Asín Palacios, M. 262, 264, 851–2
al-Aṣmaʿī 814, 816, 850
Assassins 1002
Atech, A. 875, 878–9, 884
Atomists 673
Attié, B. 261
Atto 539
Aubin, G. 210
Augustine of Hippo 717, 725, 727
Ausejo, E. 266
Autolycus 7, 18, 55
Avenzoar 925, 978, 984
Averroes: *see* Ibn Rushd
d'Avezac, M. 197
Avicenna: *see* Ibn Sīnā
Avi-Yonah, R.S. 275
Awmātiyūs 260
Axel, A. 1024
al-ʿAyyāshī 812
Ayyūbids 930–1
al-ʿAzīz (Fatimid Caliph) 185, 994

Azo 884
al-Azraq 928

Babylon 9, 454, 822–3, 826; Babylonia 334, 823, 825, 827–30, 833, 837
Babylonians 331, 333, 349–51, 765, 837
Bachet de Méziriac 402
Bacon, Roger 295, 553, 555, 557, 559, 574–5, 576, 720–1, 723, 726–9, 893, 900, 973
Badawi, A. 273, 669, 817, 1025
Baffioni, C. 885, 901
Baghdad xi, 8–11, 16, 19, 20, 23, 25, 26, 29, 31, 32, 34, 48, 49, 51, 137, 144–5, 147, 158–60, 173, 176, 188–90, 249, 267, 338, 349, 356, 372, 397, 420, 459, 505–6, 510–11, 540, 552, 587, 590, 595, 597, 599, 604, 612–13, 638, 667, 753–4, 763–4, 774, 782–3, 786, 796–7, 800–1, 803–6, 835, 908–11, 914, 917, 921, 927, 931, 934–6, 939, 941, 949, 985–99, 1002
al-Baghdādī, ʿAbd al-Laṭīf 850, 951, 995
al-Baghdādī, ʿAbd al-Qādir 815
al-Baghdādī, Ibn al-Ṭāhir 331, 341–2, 344–7, 382, 383, 386, 409–10, 412, 417
Bagrow, L. 193
Bahā' al-Dīn 550
al-Bakrī 805, 820
Balīnūs, Balīnās: *see* Apollonius of Tyana
al-Balkhī 194, 800, 804–5, 808
Balty-Guesdon, M.-G. 1006
Banqueri, J.A. 849
Banū ʿAbbād 261
Banū Mūsā 9, 26, 31, 34, 304, 383, 419–21, 444, 450–1, 453, 458, 557, 559, 618, 713, 786, 788, 790, 794, 993
Banū Naṣr 243, 271
al-Bāqir, Imām Muḥammad 864
Bar Hebraeus: *see* Ibn al-ʿIbrī
Barani, S.H. 187
Barcelo, C. 256, 270
Barkechli, M. 595, 612
Barmecides 865, 987
Barmore, F.E. 156
Barros 225
Bartholomeu Dias 203
Bartholomeu of Salerno 967
Bartholomeu the English 971
Basra xii, 189, 753–4, 764, 783, 996, 998
al-Battānī 9, 11, 18–19, 22, 24, 46–49, 54, 56, 142, 254–5, 259, 277, 280–1, 287, 289–90, 292, 296, 299, 501, 510–11, 524
Bauemker, C. 1024
Baur, L. 1024
Baznad 271
Beaujouan, G. 570, 577, 968
Becker, O. 444
Bede, the Venerable 284, 569
Bedouins 907, 910
Beeston, A.F.L. 200
Bejarano, I. 275
Bel, A. 170
Benedetti 269
Benedict, S.R. 572
Ben-Eli, A. 170
Benvenutus Grapheus of Salerno 965
Berggren, J.L. 156, 194–5
Berman, L.V. 280
Bernard of Verdun 295
Bernardo el Arabigo 270
Berthelot, M. 853, 875–6, 882–4, 888, 891, 897–9, 902
Bidez, J. 883, 898
Bienewitz, P. 549, 572
Biesterfeldt, H.H. 958
al-Birjandī 59
Birkenmajer 574
al-Bīrūnī xi, 10, 12, 18–19, 22, 24, 26, 34, 49, 51–5, 57–9, 147, 153, 157, 184–5, 187–91, 194–5, 197, 291, 360, 381, 387, 392, 454, 468, 475–81, 483–4, 489–90, 494, 501–6, 508, 511, 513, 515–16, 518–19, 523, 527–8, 533–7, 577, 619, 638–40, 642, 784, 809, 944, 948
al-Biṭrūjī 17, 84–5, 126, 265–9, 275, 279, 294–5, 300, 305
Biyūn 862
Björnbo, A. 255, 562, 577, 670, 708, 1024
Blume 573
Boethius 541, 543, 551, 556, 560, 573, 968
Boilot, D.J. 52
Bolens, L. 263, 274
Bolos of Mendes 816, 856–8, 862
Bonacosa 975, 983
Boncompagni, B. xiv, 540, 571–3, 576–80
Bonfils 547
Bonine, M.E. 156
Borgnet 900
Borro 269
Bosworth 414
Bott, G. 157
Bouriant 1007
Boutelle, M. 274
Boyer, C.B. 705–6
Bradwardine, Thomas 446, 555, 557
Brahmagupta 8, 251, 348, 391–2, 449, 499
Braunmühl, A. von 518
Brice, W.C. 170, 195
Brockelmann, C. 1028
Broscius 412
Bruin, F. 10
Bubnov 573
Bughrā Khān 999
al-Bukhārī, Abū al-Faḍl 638
Bukhārā 609, 754, 764, 921
Bulgakov, P. 157

Bürgel, J.Ch. 958
Burgundio of Pisa 967
Burnett, Ch. 570, 709, 899, 901
Busard, H.L.L. 573–6, 578
Butrus al-Ilmīmī 855
Buwayhids 759
Būzjān 51
al-Būzjānī 51–2, 57–8, 147, 190, 283, 332–3, 353, 356, 371–2, 397, 409, 449–50, 456–8, 475, 484, 492, 494, 504–9, 513–14, 521–7, 534–6, 541, 656, 667
Byzance 886; Byzantia 566; Byzantium 251, 832
Byzantines 331

Cahen, Cl. 852
Cairo xi, xii, 10, 50–1, 147, 153–6, 161–2, 177–8, 182–4, 282, 459, 513, 519, 753, 774, 801, 803–4, 930–5, 939, 989, 991–4, 997, 1000–1
Calandri, Pier Maria 570
Calvo, E. 272, 275
Campagnus of Novara 292–3, 552, 555, 557, 559, 564, 575–6
Cantay 1007
Cantor 445, 572
Capella, Martianus 268, 551
Carabaza, J.M. 261, 273
Carandell, J. 256, 273
Carathéodory, A.P. 536
Cardano 415, 446, 565, 569–70
Carmody, F.J. 266, 304–5
Caro Baroja, J. 262
Carra de Vaux x, 57, 126
Casanova, P. 170
Cassiodorus 551
Cassius Felix 964
Casulleras, J. 256
Catala, M.A. 255, 274
Cattin, P. 576
Caussin de Perceval ix
Cavalieri 431
Celebi 225
Cézard, P. 897
Chabás, J. 265
Chabrier, J.C. 590, 613
Chang Hêng 449
Cheikho, L. 1006
Chejne, A.G. 1023
Chernis, H. 706
Chevreul, E. 900
China xii, 19, 52, 150–1, 191, 204, 271, 761, 784, 789, 812, 830, 946
Chingiz-Khān 468 (see also Gengis Khān)
Chioniades 303
Chuquet, Nicholas 550, 569–70
Cicero 552, 1021
Clagett, M. 415, 552, 556, 573–7, 616, 622
Clairaut, A.C. 475
Clement-Mullet 849
Cleopatra 861
Cluzan, S. 157
Cohen, M.R. 705, 707
Colin, G. S. 275
Colombo, R. 979
Columella 247, 846–7
Comes, M. 256, 258, 265, 274
Comte, A. 1036
Condorcet ix
Conrad, L. 1006
Constantine the African 539, 717–18, 964–5, 967, 969–70, 981
Constantinople 193, 493, 797, 812, 858, 907, 910, 921, 927, 986, 1005
Coolidge 446
Copernicus 103, 107–8, 111–14, 122, 125, 259, 281, 287, 289, 297–303, 305
Corbett 898
Corbin, H. 853, 882–4
Córdoba xii, 155, 156, 163–4, 244–6, 248–55, 259, 261, 753, 764, 783, 803–5, 872, 920, 926, 931
Cornford, F.M. 705
Cortabarria Beitia, A. 275, 1024
Cossali 566
Creutz, R. 570
Crisciani, Ch. 894
Crombie, A.C. 704–6, 711, 729
Crosby, H.L. 575
Cruz Hernandez, M. 264
Ctesibius 785
Curtis, R.J. 957
Curtze, M. xiv, 572, 574–5, 580

al-Ḍabbī, ʿAbd al-Wāḥid b. Isḥāq 245
Dagomari, P. 569
al-Dakhwār (Ayyūbid ruler) 931, 939–41, 1000–1
Dales, R.C. 973
Dallal, A.S. 99, 156, 199
Damascus xi, xii, 8, 19, 25–6, 31–2, 48, 108, 131, 144, 147–8, 157, 163, 165–8, 179–84, 189, 244, 266, 270, 281, 338, 348, 601, 754, 764, 909–10, 931–5, 937, 939, 950–1, 955, 980, 993, 995, 999–1001
Daniel of Morley 895, 901
Dardi 358
Darendelī 182
Darmstaedter, E. 899
al-Dashtāghī, Manṣūr b. Muḥammad 59
David 862, 1024
Davidian, M.-L. 184
De Young, G. 573
Debarnot, M.-Th. 56, 195, 536

Deetz, C.H. 194–5
Deidier 411
Deladrière, R. 853
Delambre, J.B. ix
Delezenne 585, 596–7
Delpont, E. 157
Democritus 268, 455, 471, 473, 709, 711, 816, 847, 850, 855, 861, 869, 874
Descartes 362, 369, 410–11, 487, 672, 703–4
Despars, J. 978–9
al-Dhahabī 928
Dhū al-Nūn al-Miṣrī 864
Dickson, L.E. 346
Dicuil 284
Didymus 644
Dietrich, A. 264, 851
al-Dimashqī, Abū ‘Uthmān 553
al-Dimashqī, Ibn al-Malik 380, 413–14
al-Dimashqī, Shams al-Dīn 808
al-Dimyāṭī 135
al-Dīnawarī, Abū Ḥanīfa 395, 813–17, 821–39, 850–1
Dino del Garbo 971
Dinostratus 455
Diocles 445, 455, 644, 656, 669
Diocletian 854
Diodorus 476, 478
Diogenes Laertius 706, 1030
Diophantus 18, 346, 349–51, 356, 371, 397–402, 404, 416, 561, 564, 569, 577
Dioscorides 251–2, 264, 271, 813, 817–19, 827, 907
Dizer, M. 170
Djebbar, A. 258
Dols, M.W. 956, 958, 1007
Dominicus de Clavasio 556
Dominicus Marrochinus 983
Dominique (monk) 888–9
Dondi, Giovanni de' 789
Doresse, J. 882–3
Dozy, R.P.A. 200, 274
Drabkin, I.E. 705, 707
Dtrūms 644
Dubler, C.E. 251
Duhem, P. ix, 267, 294, 304, 614
Dureau-Lapeyssonie, J.M. 974

Eastwood, B.S. 708–9, 722, 728
Eche, Y. 987, 998, 1006
Ecphantus 870
Edessa 908, 986
Edirne 183
Efferarius Monachus 893
Eggebericus 553
Egmond, van 371
Eguerras, J. 275
Egypt 132, 142, 154–5, 162, 167, 168, 177, 179, 263, 270, 566, 752, 754, 763–5, 769, 771, 774, 783–4, 806–7, 810, 831, 834–5, 837, 858, 871, 930, 932, 940, 951–2, 955, 985
Eilmer of Malmesbury 249
Eisler, R. 19
Elephant, P. 576
El-Faiz, M. 261
Elgood, C. 959
Elias 1024
Elias of Cortona 899, 900
Emmanuel Bonfils of Tarascon 281
Empedocles 262, 857, 870
Enoch 890
Epicurus 673
Epstein, W. 704, 708
Eratosthenes 476, 585, 595
d'Erlanger, R. 597, 606, 612–13
Euclid 4, 7, 18, 35, 55, 258, 277, 341, 349, 351, 353, 355, 372, 408–10, 412, 419, 447, 449, 452, 455, 460–71, 482, 486, 490–1, 493–4, 551–2, 554–6, 559–60, 564, 568, 573–5, 577, 612, 615–16, 626, 631, 643–7, 651–2, 656, 660, 667, 674, 680–1, 705–6, 708, 718–19, 721, 723–4, 726–8, 872, 986, 1003, 1019, 1022, 1031
Eudemus 431
Eudoxus 267, 626
Euler, J. 404, 413, 433, 437, 454, 475, 480
Eulogius (of Córdoba) 246
Europe xii, 168, 191, 195, 197–8, 271, 349, 454–5, 475, 492–3, 496, 517, 524, 615, 634, 642, 762, 776, 782–4, 792, 794, 809, 811
Eutocius 419, 555
Ezechiel 862

Fāḍil 587
Fahd, T. 850–2
Fähndrich, H. 959
Fakhr al-Dawla 10, 504
Fakhry, M. 1032
Falloppio, Gabriele 976
al-Fārābī, Abū Naṣr 268, 438, 456–8, 471, 475, 484, 494, 492, 594–5, 597, 599, 601–5, 607–10, 612–13, 633, 644, 881, 882, 895, 1011–16, 1019, 1021, 1023, 1029, 1033–5
Faraj b. Salim 893, 978, 984
al-Farghānī 24–5, 55–6, 292–3, 478
al-Fārisī 358, 379–80, 386, 393, 401, 409–10, 412, 667–9, 671, 703
Farmer, H.G. 595, 597, 599, 612–13
Fars 759–60
Fatimids 50, 155
al-Fazārī 20–1, 54–5, 158, 163, 189
Feigenbaum, A. 959

Fermat, P. xiii, 369, 401–2, 404, 407, 410, 425, 487
Ferrand, G. 211
Festugière, A.J. 857, 862, 882–3
Fez 271, 348
Fibonacci xii, 407, 413, 493, 542, 547, 549, 555–7, 559, 561, 563–70, 569, 572, 576, 579
Ficino, Marsilio 723
Fincke, Thomas 514
Firdawsī 944
Fischer, J. 193
Flügel, G. 1023
Fobes 901
Folkerts, M. 573–4
Fontana, G. 560
Francesco Pellos 549
Francis of Assisi 900
Francis of Ferrara 557
Franco of Liege 551
Frank, J. 19, 184
Frederick II of Hohenstaufen 560
Füch 883
Fulbert 551
Fusoris, John 560
Fusṭāṭ 155, 783, 926, 934, 990

Galen 74, 249–50, 262, 644, 676, 680, 682–3, 689, 702, 705–14, 717, 721, 724–5, 727, 818–19, 883, 907, 911–13, 917–19, 927, 940, 951–2, 957–8, 964, 967–8, 970–1, 974–9, 986, 992, 995
Galenists 726
Galileo xiii, 269
Gandz, S. 266, 278
Ganzenmüller, W. 853, 900
Garbers, K. 169, 957
Garcia Ballester, L. 271, 273
García Sánchez, E. 261, 275
Garcia the Cardinal 876
Gardet, L. 1023
Garijo, I. 252
Garlande 284, 873
Gauthier, L. 126, 264
Gengis Khān 1002
Gerard of Brussels 557
Gerard of Cremona 265, 287, 292, 296, 304, 553, 555–7, 560, 562–3, 566, 578, 718, 818, 877, 892, 895, 970–1, 979, 982, 1024
Gerard of Solo 972
Gerbert of Aurillac (Pope Sylvester II) 285, 539–40, 551, 556, 570, 578
Geymonat, M. 573
al-Ghāfiqī 264, 271, 819
Ghaligai, Francesco 570
Ghanem, I. 283
al-Gharnāṭī, Abū Ḥāmid 263, 808, 811
al-Ghazālī 955, 1008
Ghazna 51, 147, 190, 990
al-Ghundijānī 667
Gianbattista Nicolosi 197
Gilbert the Cardinal 876
Giles of Rome (Aegidius) 976
Giles of Santarem 983
Gilgamesh 839
Gilson, E. 898
Girardus Bituricensis 971–2
Glick, T.F. 262
Gmoll, G. 850
Goeje, de 200
Gog and Magog 797
Goiten, S.D. 283, 958
Goldstein, B.R. 81, 126, 184, 253, 260, 264–5, 267, 276, 278–83, 304–5
Gonzalez Palencia 1024
Grafton, A. 107, 113
Granada xi, 243, 269–71, 764, 935, 972, 1006
Grant, E. 269, 305, 575, 707, 719, 729, 958
Grau, M. 274
Greenhill, W.A. 957
Gregorios 862
Grignaschi, M. 1025
Grosseteste, Robert 294, 553, 719–20, 723, 726–7, 729, 973
Guichard, P. 273
Guidi, M. 1023–4
Gundīshāpūr 8, 337, 908, 910–11, 917, 934, 991
Gundissalinus 542, 894, 901, 1024–5
Gurgān 921
Gutas, D. 1024

Ḥabash al-Ḥāsib 9, 25, 31–4, 41, 54, 57–8, 144, 176, 181, 184, 189, 250, 256, 476, 501, 511–12, 524, 529–30, 533
al-Ḥabīb 860–1
al-Ḥadib 282–3
Ḥāfiẓ-i Abrū 201
Hahm, D.E. 705–7
Hairetdinova, N.G. 535
al-Ḥajjāj al-Thaqafī 764
al-Ḥajjāj b. Yūsuf b. Maṭar 22, 30, 351, 419, 445, 552–3
Ḥājjī Khalīfa 370, 864
al-Ḥakam II 248, 250, 872
al-Ḥākim (Fāṭimid ruler) 51, 154–5, 949, 989, 990, 994
al-Ḥalabī 380
Hall, S.T. 704
Halleux, R. 573, 882, 897, 900–1
Halliwell, J.O. 571–2
Halma, N. 56
Halyā b. Sarjūn 22
Hamadanizadeh, J. 415, 537–8

Ḥamadhān xii, 921, 926
Hamarneh, S. 274, 957
al-Hamdānī 189
Hamdīn b. Ubba (Oppas) 246–7
Ḥamīdullāh, M. 815
Hammar-Purgstall 225
Hammer, J. 414
Hamuel 870
Ḥanash al-Ṣan'ānī 244
Hanson, N.R. 672
al-Harawī 810
al-Ḥārith b. Kalada 908
Ḥarrān 34, 46, 911, 986
al-Ḥarrānī 249; Aḥmad 249; 'Umar b. Yūnus 249
Hartner, W. 54, 274, 304–5
Hārūn al-Rashīd 865, 910, 934, 985–7, 991–2, 997
al-Ḥasan b. Mūsā 425
al-Ḥasan b. Quraysh 22
al-Hāshimī 19, 56, 253, 274, 355
Haskins, C.H. 539, 541, 574
Hatfield, G. 704, 708
Hawkins, G.S. 156
Hawthorne, J.G. 898
Heath, Th. 444, 557
Hegel 1028, 1035
Heiberg, J.L. xiv, 56, 494
Heinen, A. 958, 998, 1007
Heraclitus 857
Heraclius 856, 862
Herman of Carinthia 552–3, 574, 894
Hermann (Archbishop of Cologne) 573
Hermann of Dalmatia 255, 285
Hermann the Lame 285–6
Hermelink, H. 258
Hermes 855–6, 858–9, 861, 869, 874, 890–1
Hero of Alexandria 341, 438, 448–50, 576–7, 615–18, 633, 643–5, 649, 656, 705, 785, 788
Hicks, R.D. 706
Hiero 638
Ḥijaz 168, 827
Hill, D. 709, 713
Hipparchus 4, 6, 8–9, 28–31, 259, 495, 855
Hippias of Elis 455
Hippocrates 246, 250, 252, 262, 855, 907, 913, 916, 918–19, 927–8, 938, 977–8, 986
Hippocrates of Chios 418, 431–3, 445
Hippolytus 870
Hīrā 581
Hire, Philippe de la 197
Hirschberg, J. x, 709, 714
Hishām 244–5
Hofmann, J.E. 575
Hogendijk, J.P. 254, 258
Holmyard, E.J. 260, 853, 859, 872, 874, 883, 900–1
Homer 860
Homs 759, 999
Honigmann, E. 189, 199
Honofredi, Bernardus 984
Houzel, Ch. 465
al-Ḥubūbī 353
Hudry 722
Hugh of Santalla 890, 894
Hugonnard-Roche, H. 265, 1024–5
Hugues, B.B. 577–9
Hugues de Saint Victor 554, 556
Hūlāgū Khān 14, 58, 301, 468, 1002–3
Humboldt, Alexander von x
Hume, D. 1029
Ḥunayn b. Isḥāq 21, 55, 644–5, 647, 680, 682, 708–9, 713–4, 717, 722, 727, 905, 911, 919, 932, 940–2, 948, 958, 963, 965, 970, 981, 983, 995
Hunger, H. 415
al-Ḥusayn b. Bisṭām b. Sābūr 928
Hypsicles 7, 19, 55, 346

Iamblichus 346
Iberian peninsula 243, 783–4
Ibn 'Abd al-Bāqī, Muḥammad 553, 560
Ibn 'Abdūn 543
Ibn Abī al-Bayān al-Isrā'īlī 931
Ibn Abī Rimtha 908
Ibn Abī Ṣādiq al-Nīsābūrī 942
Ibn Abī Turāb 358
Ibn Abī Uṣaybi'a 712, 860, 931–2, 939, 949, 958, 988, 992, 995, 1000–1, 1006, 1028
Ibn al-Ādamī 160
Ibn Aflaḥ: *see* Jābir
Ibn Āmājūr, 'Alī 173–4, 176
Ibn al-'Amīd 916
Ibn al-A'rābī 134
Ibn Arfa' Ra's 857, 873–4
Ibn Arqam al-Numayrī 272
Ibn 'Āṣim, 'Abd Allāh b. Ḥusayn (al-Gharbāl) 257, 274
Ibn 'Aṭiyya, Abū al-Majd 387
Ibn al-'Awwām 247, 261–4, 272, 848–9
Ibn al-'Aynzarbī 931
Ibn Badr 271
Ibn al-Baghdādī 502
Ibn Bājja (Avempace) 244, 258, 263–4, 266–8, 278, 818, 1029
Ibn Bakhtīshū', family 934, 938
Ibn Bakhtīshū', Jibrā'īl 669, 910, 991–2
Ibn Bakhtīshū', Jurjis b. Jibrā'īl 910
Ibn Bakkūsh, Ibrāhīm 817
Ibn Bakus, Ibrāhīm 992
Ibn al-Bannā' 272, 338–9, 358–9, 371, 380, 410, 412, 550

Ibn Barza 370
Ibn Bāsō 272–3
Ibn Baṣṣāl 257, 261–2, 848
Ibn Baṭṭūṭa 812, 819
Ibn al-Bayṭār 264, 270–2, 816, 819, 821–39
Ibn Bishrūn, Abū Bakr 879–80
Ibn al-Biṭrīq 669, 895
Ibn Buklārish 263, 275
Ibn Buṭlān 263, 927, 939, 984, 992
Ibn Durayd 857
Ibn Faḍl Allāh al-ʿUmarī 807, 811
Ibn Faḍlān 798
Ibn Fallus 413
Ibn al-Faqīh 799–800, 808, 810
Ibn Fatḥ, Sinān 571
Ibn Fāṭima 811
Ibn Firnās, ʿAbbās 248–50
Ibn Ghaybī Maraqī 612
Ibn Ghāzī al-Miknāsī 348
Ibn al-Hā'im 265, 273
Ibn al-Ḥājj, Muḥammad 271
Ibn Ḥajjāj 247, 273
Ibn Ḥajjāj al-Ishbīlī 846–7
Ibn al-Ḥaṣṣār 382
Ibn Ḥawqal 194, 762, 800–1, 810, 820, 851
Ibn al-Haytham (Alhazen) xi, xii, 17, 19, 49, 55, 57–8, 74–82, 84–5, 147, 156, 258, 280, 295, 298, 303, 305, 383–6, 402, 405, 408, 409, 412, 417–18, 425, 427–37, 440–5, 450, 459, 462–3, 466, 468, 470–1, 477, 484, 493, 519, 533, 558–60, 568, 570, 575, 619–21, 623–5, 646, 651–2, 656–7, 660–70, 686–716, 718–20, 722–9, 965
Ibn Ḥayyān: see Jābir
Ibn Ḥazm 1008
Ibn Hibinta 253
Ibn Hūd 244, 258, 409–10
Ibn al-ʿIbrī, Abū al-Faraj 465, 1003
Ibn Ilyās 952–3
Ibn ʿImrān, Isḥāq 818
Ibn ʿIrāq, Abū Naṣr 51–2, 176, 184, 360, 372, 483, 505–9, 512, 516–17, 534–5
Ibn ʿIrāq, al-Manṣūr b. Naṣr 58
Ibn ʿĪsā, Aḥmad 656
Ibn ʿIṣma, Sulaymān 355, 502
Ibn al-Jawzī 909, 928, 957
Ibn Jazla 263, 998
Ibn al-Jazzār 818, 927, 964, 968, 981
Ibn Jubayr 763, 812, 992, 999
Ibn Juljul al-Andalusī 246, 249, 264, 893, 1028
Ibn Jumayʿ al-Isrā'īlī, Hibat Allāh 926, 931, 952, 959
Ibn al-Kammād 265
Ibn al-Kattānī 818
Ibn Khātima 972
Ibn Khalaf, ʿAlī 257
Ibn Khalaf al-Murādī 261
Ibn Khaldūn 766, 806, 854, 875, 879–82, 907, 929, 957–8, 1008, 1028
Ibn Khalliqān 997
Ibn al-Khashshāb 358
Ibn al-Khaṭīb 269, 271–3, 275, 972
Ibn al-Khawwām 358, 386, 415
Ibn Khurdādhbih (Khurradādhbih) 137, 797–8, 800, 802, 807
Ibn al-Layth: *see* Abū al-Jūd
Ibn Luyūn 271–2
Ibn Mājid 202–3, 205, 207–14, 216–18, 220, 222–6, 228–32, 233–5, 237–42, 811
Ibn al-Makkī 980
Ibn Mammātī 849
Ibn Maʿrūf: *see* Taqī al-Dīn
Ibn Māsawayh 645, 669, 818, 910, 941, 948, 977–8, 982–3, 994
Ibn Masrūr al-Naṣrānī 655
Ibn Muʿādh al-Jayyānī 244, 258, 265, 279–80, 517–20, 536, 718
Ibn al-Mughayribī 880
Ibn al-Murakhkhīm 667
Ibn al-Muthannā 253, 278, 817
Ibn al-Muṭrān 931, 988
Ibn al-Nafīs 931–3, 951, 958, 979–80
Ibn Nāṣiḥ, ʿAbbās 248–9
Ibn Qalā'ūn, al-Nāṣir Muḥammad (Mamlūk ruler) 954
Ibn al-Quff 932–3, 943, 946
Ibn Qunfūdh 272
Ibn Qurra: *see* Thābit
Ibn Qutayba 257, 849, 909, 957
Ibn al-Qūṭiyya 244
Ibn al-Raqqām 270, 273, 283
Ibn Riḍwān 926–7, 939, 954, 982
Ibn al-Rūmiyya 819
Ibn Rushd 84–5, 263–6, 268, 275, 280, 294, 305, 718, 722–3, 726, 951, 974–9, 983–4, 1029–30, 1036
Ibn Rusteh 798, 807
Ibn al-Saffār 163–4, 252, 254, 256, 285
Ibn Saʿīd 809, 811
Ibn Sahl 425, 427, 459, 481, 559, 652, 655–60, 665–7, 670
Ibn al-Ṣalāḥ 55
Ibn al-Samḥ 254, 256, 265, 880
Ibn Samjūn 818
Ibn Sarābiyūn, Yūḥannā 718, 918, 978, 982
Ibn al-Sarrāj 179
Ibn Sayyid 258
Ibn Sebüktijin, Masʿūd b. Maḥmūd (Ghaznevid Sultan) 528
Ibn al-Shaddād 164, 958
Ibn al-Shamir 249
Ibn al-Shāṭir 58, 86–90, 99, 100–3, 108–14, 120, 122, 125–7, 165–6, 168, 170, 179, 257, 281, 301–2

Ibn Shumayl, al-Naḍr 817
Ibn Sīda 814, 816
Ibn al-Sikkīt 814
Ibn Sīnā 12, 25, 103, 270, 277, 408, 417, 596, 605–6, 609, 613, 618, 633, 662, 683–5, 710–11, 718, 722–3, 726, 818, 850, 854, 875–9, 881–2, 884, 895–6, 901, 921–8, 932, 939, 943–4, 950, 954, 957, 964, 966, 970–9, 982–4, 998, 1016–17, 1019–23, 1021–3, 1025
Ibn al-Sunnī 928
Ibn Surāqa 137–9
Ibn Ṭabāṭabā 377
Ibn Ṭāhir: *see* al-Baghdādī
Ibn al-Ṭayyib 992, 1024
Ibn al-Tilmīdh 931, 940–1
Ibn Ṭūlūn (ʿAbbāsid ruler) 764, 934
Ibn Turk 352–3, 562
Ibn Ukhuwwa(h) 940
Ibn Umayl 860, 864, 870–4
Ibn Uthāl 909
Ibn Wāfid 261–2, 264, 818, 982
Ibn Waḥshiyya 261, 377, 414, 818
Ibn al-Wardī 139, 808, 850
Ibn Yaḥyā al-Waṭwaṭ al-Kutubī, Jamāl al-Dīn Muḥammad 846
Ibn Yūnus 8, 10, 15, 16, 19, 26, 49–51, 147, 155, 177, 185, 282, 391, 402, 405, 496, 501, 513, 524–5, 528, 536, 994, 997
Ibn Yūsuf, Aḥmad 555–6, 560
Ibn Zangī, Nūr al-Dīn Maḥmūd (Ayyūbid ruler) 930, 999, 1001
Ibn al-Zayyāt al-Tādilī 268
Ibn Zuhr 925–6, 984
Ibn Zuhr, family 939
Ibrāhīm b. Sinān 304, 425–6, 450, 458, 473–5, 478, 494
Id, Y. 156
al-Idrīsī 185, 199–200, 763, 783, 809, 811, 819–20
Ifrīqiya 245, 273
Ikhwān al-Ṣafāʾ 249, 850, 872, 1008
ʿImrān 988
India xii, 15, 20, 52, 55, 133, 189, 200, 203–5, 334, 337, 761, 784, 802, 809, 812, 819, 823–4, 828–31, 833, 835, 903, 946, 949
Indian Ocean 202–5, 209–10, 212, 220, 229, 231–2, 241
Iran 13, 19, 58, 86, 138, 142, 149, 151, 159, 189, 335, 380, 581, 755–6, 759, 762–5, 775, 782–3, 799, 801–2, 812, 956, 1003
Irani, R. 184, 535
Iraq 131–3, 138, 335, 753–4, 758–9, 763, 775, 784, 788, 805–7, 925, 934, 949
al-ʿIrāqī, Abū al-Qāsim (al-Sīmāwī) 874, 893
ʿIsā, A. 958
ʿIsā b. ʿUmar al-Thaqafī 814
Isfahan 10, 13, 50, 150–1, 763–4, 819, 985, 995
al-Iṣfahānī 598–9, 612, 957
al-Isfizārī 620, 623–8, 634–5
Isḥāq b. Ḥunayn 21–2, 55, 552–3, 817, 905, 919
Isḥāq b. Imrān 964
Isḥāq b. Sīd 261
Isḥāq b. Sulaymān al-Isrāʾīlī (Isaac Israeli) 279, 818, 964, 970, 981–2
al-Ishbīlī: *see* Abū Khayr, Ibn al-ʿAwwām, Ibn Ḥajjāj
Isidore 894, 977
Isidore of Seville 245–6, 551, 716, 725
Iskandar, Z. 709, 884, 957–9
Issa Bey, A. 991, 1006–7
al-Iṣṭakhrī 194, 754, 763–4, 783, 800
Istanbul 14, 163, 182–4, 257, 587, 956
Iṣṭifān b. Basīl 251
Italy 566, 759, 971

Jacob Anatoli 901
Jacquart, D. 709, 983, 1007
Jābir b. Aflaḥ 84, 126, 264–6, 278, 280, 282, 446, 509
Jābir b. Ḥayyān 853–5, 861, 864–9, 873, 877, 880, 884, 891
Jaʿfar al-Ṣādiq 864–5
al-Jaghmīnī 59, 480
Jāḥiẓ 857
Jaipur 15
Jaï Singh 15
Jalāl al-Dawla Malikshāh 15
Jaldakī 854, 859–61, 864, 873–4, 893
Janin, L. 157, 170
Jaubert, A. 199
Jawād 247
al-Jawbarī, ʿAbd al-Raḥīm b. ʿUmar 937
al-Jawharī, ʿAbbās 464, 468–9
Jawzajānī 879
al-Jazarī 618, 713, 776, 779, 789–90, 794
Jean (monk) 856
Jean le Bègue 889
Jensen, C. 184
Jerusalem 131, 137, 184, 189, 764
Jesus 862
Job of Edessa 711, 817
Johannes de Tinemue 557
Johannes Garlandus 873
John David 542, 571
John of Capua 984
John of Murs 297, 568
John of Palermo 560
John of Sacrobosco 543, 547–9
John of Saint-Amand 972–3

John of Seville (Iohannes Hispalensis) 285–6, 292, 304, 542, 561, 966, 982
John of Sicily 296
John of Toledo 544, 547, 549, 561–3, 565
John of Tournemire 972
John the Evangelist 876
Jolivet, J. 707–8, 1025
Jones, W. 454
Jordan 753, 825, 831
Jordanus Nemorarius xii, 555–8, 563–5, 569, 575–6, 578, 622
Joseph b. Yehūdah b. Sham'ūn 266
Joseph the Wise (Josephus Hispanus) 570
Julian the Apostate 918
Junge, G. 574
Jūniūs 847
al-Jurjānī 610, 613
Juynboll, G.H. 19
al-Jūzjānī, Abū 'Ubayd 58, 103–5, 112, 417
al-Juzūlī 850

Kahle, P. 851
Kahn, H. 414, 706
Kairouan 387, 964, 755, 935, 964
Kalonymos b. Kalonymos 280
al-Kalwadhānī 571
Kamāl al-Dīn b. Yūnus 369
Kamal al-Dīn al-Turkumānī 480
Kant 1029
al-Karābīsī 409, 571
al-Karajī 332–3, 348, 355–9, 369, 376, 378, 380, 384, 389, 397–401, 409–10, 416–17, 450, 546, 564, 566, 568–70, 1016
Karpinski, L.C. x, 570
al-Kāshī 59, 187, 191, 341, 346, 358, 380–1, 383, 387–91, 393, 414–15, 450, 452–4, 496, 509–10, 521, 531–2, 538, 550, 1005
Kassianos Bassos Scholasticos 816 (= Quṣṭūs)
Kāth 190, 505
Kautilya 870
Kennedy, E.S. 19, 21, 56, 118, 126, 156, 184, 187–91, 195, 200, 253–4, 257, 265, 280, 284, 291, 303, 533, 538, 1007
Kepler, J. xiii, 107, 113, 284–5, 291, 303, 431, 493, 530, 575, 672, 716, 727
Kersey, J. 412
Keuning, J. 199
Khadr, M. 998, 1007
Khālid b. Yazīd 247, 861–2, 864, 889, 893, 909, 986
al-Khalīl b. Aḥmad 377–8
Khalīl b. Aḥmad al-Farāhīdī 814
Khalil Samir 669
al-Khalīlī 147–8, 176, 179–81, 184
al-Khāzin 49, 57, 256, 355, 360, 371–2, 391, 393, 402–4, 406, 412, 417, 438–41, 501, 505, 512, 515–17
al-Khāzinī 618–42
Kharaqī, 'Abd al-Jabbār 479–80, 484
al-Kharaqī al-Thābitī 57
al-Khayyām xii, 13, 359–64, 369, 371, 387, 401, 450, 463–4, 467–71, 539, 569–70, 579, 619, 638–40
al-Khilāṭī 369, 375, 402, 413
Khoury, I. 211, 226, 228
al-Khujandī, Abū Maḥmūd 10, 11, 51, 52, 402, 404, 503–5, 513, 533
Khurāsān 49, 604, 607–9, 612–13, 754, 784, 822, 832, 835–6, 874
Khusraw Anūshīrawān (Sāsānian ruler) 908
Khwārizm 51, 200, 372, 468, 479–80, 503, 505, 819
al-Khwārizmī, Abū 'Abd Allāh 18, 618, 632, 1008
al-Khwārizmī, Muḥammad b. Mūsā xii, 21, 23, 33, 54, 58–9, 158–9, 169, 173, 188, 193, 248, 250, 252–4, 258–9, 278, 287, 289, 331, 333–4, 336, 349–56, 370, 376, 382–3, 385, 394–5, 397, 415–16, 448–9, 464, 484–6, 489, 493, 501, 510–11, 539–48, 550, 561–4, 566, 570–2, 578, 796, 1016
Kiesewetter 613
al-Kilābī, Abū Zayd 814
al-Kinānī, 'Abd al-Malik b. Abjar 909
al-Kindī, Ya'qūb b. Isḥāq 23, 55, 252, 264, 377, 417, 419, 438, 446, 457, 468, 483–4, 541, 560, 597–9, 612, 630, 644–7, 649–56, 669, 680–3, 707–8, 718–20, 723–4, 726–7, 854, 860–1, 882, 957, 973–4, 982, 1009–11, 1015–16, 1022–5
King, D.A. 21, 156, 169–70, 184, 254, 256, 273–4, 536–7
al-Kisā'ī 814
Knorr, W. 728
Korah (Qārūn) 862
Kosegarten 595
Kraemer, J. 1006
Kramers, J.H. 194
Kraus, P. x, 853, 865, 883–5, 899
Kroll, W. 850
Kühne, R. 247
Kunitzsch, P. 55, 254, 277, 304, 574
Kūfa 134, 764, 865
al-Kūhī: *see* al-Qūhī
Kūshyār b. Labbān 282–3, 382–6, 504, 513, 548, 568

Labarta, A. 256, 275
Lacombe, O. 901
Lacy, de 705–7, 713
al-Lādhiqī 612–13

Lagarde, P. de 850
Lakhmids 581
Lambert, J.H. 454, 466, 470
Langermann, Y.T. 32, 283
Langhade, J. 1025
Laurencie 612
Lavignac, A. 612
Leclerc, L. 275, 884, 991, 1006
Lee, E.N. 705
Lefèvre d'Etaples, J. 575
Leiser, G. 958
Lejeune, A. 705, 728
Lemay, R. 304, 571, 892
Leo Africanus 271
Leonardo of Cremona 559
Lettinck 269
Leucippus 870
Levey, M. 275, 567, 571–2, 578–9
Levi b. Gerson 279–81, 470–1, 493
Levi della Vida, G. 900
Levinova, I.S. 634
Lewin, B. 815, 850
Lewis, G.L. 870, 959
L'Huillier, G. 579
Libri, G. xiv, 577–9
Lindberg, D.C. 669, 704–12, 718, 721–3, 728–9, 965–6
Lindemann, F. 454
Lippert, J. 709, 714, 1007
Lippmann, E.G. 853, 882–5
Livesey, S. 184
Llobet of Barcelona 285–6
Lopez, A.C. 273–4
Lorch, R.P. 157, 265, 275, 446, 573–4
Lory, P. 853, 884
Lotharingia 551
Lovejoy, A. 1029
Luckey, P. x, 169, 381, 414, 501, 534, 538
Lucknow 900
Lucretius 268

McCue, J.F. 575
McCulloch, F. 898
McEvoy, J. 728
MacGuckin de Sane 1007
Macrobius 968
McVaugh, M.R. 274, 925, 958, 973–4
Maestlin 107–8, 113
Maghrib 15, 21, 165, 171, 181, 245, 270, 766, 806, 1005
al-Maghribī, Muḥyī al-Dīn 14, 270, 481–2, 527
al-Māhānī 9, 354–5, 357, 360, 371, 372, 421, 426, 485–6
Mahdi, M. 1024–5
Maḥmūd b. Ghazna (Sultan) 990
al-Mahrī, Sulaymān 202, 204–5, 208–14, 216–18, 220, 222, 224–6, 228–32, 234, 237–8, 242, 811
Maimonides (Mūsā b. Maymūn) xii, 263–4, 266, 278, 282–3, 819, 931
Majno, G. 959
al-Majrīṭī, Maslama 15, 21, 249–50, 252–60, 285, 287, 872, 880
al-Majūsī, ʿAlī b. al-ʿAbbās 917–22, 925–6, 936, 943–4, 957–8, 964, 966–8, 972, 976, 981–2
Makdisi, G. 995, 1007, 1023
Makhoul, N. 613
al-Makhzūmī 849
Makkī, M. 274
al-Malik al-Afḍal 257
Malikshāh 13, 14, 873
Mamlūks 155, 807, 930–1, 955
al-Ma'mūn 8–9, 21–2, 24–6, 31, 34, 48, 50, 56, 83, 187, 193, 253, 260–1, 289, 370, 552, 786, 796, 818, 859, 910, 985–9, 993, 997
Mandeville 884, 901
Manget, J.J. 898–9
Mani 862
Mannol 587
al-Manṣūr (Caliph) 20, 910, 918, 986
al-Manṣūr b. Abī ʿĀmir 246
Maqbul Ahmad, S. 185, 193, 200
al-Maqdisī: *see* al-Muqaddāsī
al-Maqqarī 275
al-Maqrīzī 989, 991, 994, 1000, 1002
al-Maqsī 161–3, 168, 177
Marāgha xii, 12–15, 19, 58–9, 86, 270, 301, 338, 462, 481, 518, 527, 1002–5
Marcellus 645
Marchionis, G. 296
Marco Polo 210, 784
Marcus Junius Nipsus 573
al-Mārdīnī 375
Margoliouth 1006
Maria 861–2
Marianos 862, 864, 889
Marin, M. 245, 273
Marinus of Tyre 191–4, 200, 476
Mark of Toledo 983
Marquet, Y. 1023
Marrakesh 264, 272
al-Marrākushī 161–3, 167–169, 177–8, 184, 459
Marre, A. 579–80
Marsh, R. 553
Marti, R. 255, 274
Martinez, L. 275
Marw 479, 754, 912
Māsā al-Sūrānī 839
Māsarjawayh (Māsārjīs) 909

Māshā'allāh 255, 277, 282, 286
Mashriq 244
al-Mas'ūdī 23, 55, 193, 784, 798, 807, 860–1
Matthew 862
Maurolycus 514
Maurus 967, 969
al-Mawṣilī, Ibrāhīm 599
al-Mawṣilī, Iṣḥāq 597–9, 612–13
May, M.T. 706, 711, 713–14
Mead, R. 957
Mecca (Ka'ba) 15, 128–57, 181, 476–80, 500, 935, 989, 1036
Medina 909, 935
Mehmet II (Sultan) 193
Menaechmus 455, 486
Menelaus 7, 19, 55, 145, 421, 448, 482–3, 495, 497, 499–501, 505–6, 508, 514–16, 518, 520, 532–3, 535, 560, 617, 630, 638
Menendez Pidal, G. 246
Mercier, R. 259, 304
Mesopotamia 34, 775, 783, 784, 805, 810, 819, 832, 835–8, 911, 1003
Meyerhof, M. 249, 251, 264, 669, 708–9, 711, 851, 957–8
Meyvaert 897
Micheau, F. 1006–7
Michel, H. 170
Michot, J. 1025
Millás Vallicrosa, J. 198, 253–4, 256, 259–60, 274, 277, 304, 852
Millás Vendrell, E. 253
Miller, K. 199–201
Mimoune, R. 1025
Mingana, A. 711, 850
Minio Paluello 900
Miura, N. 579
Mīzrahī 415
al-Mizzī 179
Möbius 475
Mogenet, J. 445
Molina, L. 248
Monge, G. 482
Monteil, V 1023
Montmort, P.R. de 412
Montucla, J.E. ix
Moody, E.A. 269, 616, 622
Moraux, P. 1024
Morelon, R. 18, 44, 56, 304–5
Morocco 380
Moses 862
Moshe b. Tibbon 279
Mosul xii, 990, 997–8
Mouliérac, J. 157
Mu'āwiya (Umayyad Caliph) 909
al-Mu'ayyad (Sultan) 179
Mubashshir 860
al-Mubashshir b. Fātik 988
Muhadhdhab al-Dīn 1001
Muḥammad (Emir 852–86) 246, 248, 250
Muḥammad (Prophet) 130, 177, 753, 907, 927–9, 956, 1010
Muḥammad Bāqir Yazdī 151
Muḥammad I 271
Muḥammad II 270–1
Muḥammad II Fātiḥ (Ottoman ruler) 921
Muḥammad Ḥusayn 151, 153
Muḥammad al-Shafra 270–1
Müller, D.H. 189
al-Munajjim 597, 599, 612
al-Munajjim, 'Alī b. Yaḥyā 989
al-Munajjim, Yaḥyā 997
al-Munāwī, Nūr al-Dīn 'Alī b. Muḥammad al-Shāfi'ī 933
al-Mundhir 246
Munk, S. 672
Muñoz, R. 245
al-Muqaddasī 137, 194, 759, 783, 800, 801–4, 811
Muqattam (Mount) 50
al-Murādī 788–9
Murcia 269, 761
Murdoch, J.E. 552, 573–4, 577, 707
Musallam, B. 708
Musharrafa, 'A. 578
al-Mustanṣir (Fatimid Caliph) 926
al-Mu'taman: *see* Ibn Hūd
al-Mu'taṣim 669
al-Mutawakkil 817, 911–12, 988
al-Muwaffaq, Abū Manṣūr 869
Muwaffaq al-Dīn Ya'qūb al-Sāmirī 942
Mžik, H. 193, 200

Nabateans 753
al-Nadīm 348, 352, 438, 446, 540, 644–5, 655, 670, 817, 855, 857–8, 861–2, 864, 1008, 1028
Nadir, N. 184
Nagelberg, S. 850
Najm al-Dīn 178
Nallino, C.A. x, 18, 188, 193, 195, 254, 850
al-Nasawī xi, 382, 568, 576
al-Nāṣir Ṣalāḥ al-Dīn, al-Malik 926, 930–1, 934, 940, 952, 990
Naṣr (Sultan 1309–14) 270
Nau, F. 899
al-Nayrīzī 54, 143, 145, 464, 501, 504, 512, 533, 552–4, 556, 560, 575, 619, 638
Nazif, M. x, 661, 669, 712–13
Nedkov, B. 200
Needham, J. 19, 347
Nemesius of Emesa 859, 965–6
neo-Archimedeans 418
neo-Pythagoreans 408
Nestorians 910–11, 934

Neugebauer, O. x, 18, 21, 55–6, 61, 104, 122, 125–6, 191, 198, 252–3, 278, 304–5, 391, 415, 532–4
Newman, W. 897, 902, 899, 902
Newton 528
Nicholas (monk) 251–2, 255
Nicholas of Damascus 817
Nicholas of Reggio 971
Nicomachus of Gerasa 341, 346–7, 408–9, 413, 541, 552
Nicomedes 455
al-Nihāwandī 8
Nishāpūr 9, 996
Niẓām al-Mulk 996
Noe 890
North, J. 304, 575
al-Nu'aymī 1001
al-Nubātī 811–12
Nutton, V. 713, 1006
Nūr al-Dīn al-Zanjī (Ayyubid Sultan) 167
al-Nuwayrī 807, 850

Ocreatus, N. 553, 574
Oder, S. 850
Oliver Asín, J. 262
Olympiodorus 644, 669, 855, 860, 870, 1024
Onnik 587
Oresme, N. 555, 557
Oribasius 918, 964
Orosius, P. 246
Ostanes 855–6, 858, 861–2, 874
Otte 901

Pacioli, L. 550, 559, 569, 579
Palestine 130, 753
Pappus of Alexandria 7, 438–9, 445–6, 553, 557, 615
Paracelsus 865, 897
Parmenides 857
Pascal 379
Pasch, M. 466
Pastore, N. 707
Paul of Aegina 918, 921, 940, 942
Paul of Persia 1024
Paulus of Taranto 897
Pecham, J. 721, 727–8
Pedersen, O. 9, 126, 304–5
Pellat, Ch. 274
Pellos, F. 570
Peripatetics 1021
Persia 8, 16, 49, 51, 334, 828, 834–5, 908, 921; Ṣafavid 955
Peter of Saint-Omer 296
Peter the Venerable 562, 890
Peters, F.E. 1023
Petersen, V.M. 126
Petraitis, C. 885, 901
Petruck, M. 571–2
Petrus Alfonsus 541–2, 571
Petrus Apianus 549
Petrus Hispanus 971
Petrus Musandinus 967
Peurbach, G. 295, 298–9, 305
Philo of Byzantium 785, 788
Philon 617
Philoponus 267–8, 677–8, 707, 1030
Piero Borghi 549
Piero della Francesca 563, 570
Pierre de la Ramée 559
Pietro d'Abano 976–7
Pinès, S. 57, 280, 707, 709–10, 884, 957
Pingree, D. 55, 249, 253, 282
Pisano, Leonardo: *see* Fibonacci
Planudes, Maximus 549
Platearius, Matthaeus 968–70
Plato 651, 675, 680, 705–6, 717, 721, 725–7, 855, 861, 865, 913, 965, 986, 1020–1, 1024–5, 1028, 1030–1, 1033–5
Plato of Tivoli 285, 287, 304, 492–3, 542, 563, 891
Plessner, M. 853, 883, 900
Pliny 894, 717, 728; Pliny the Elder 716
Plooij, E.B. 258
Plotinus 707, 721–3, 1029–30, 1032
Plutarch 854
Polyak, S. 704
Posidonius 464
Postel, G. 195
Poulle, E. 270, 274, 296, 304–5
Prémare, A.L. de 263
Princep 225
Proclus 464, 556, 707, 855, 1030, 1032
Profatius 288, 297, 304, 984
Psellos 886
Pseudo-Apollonius of Tyana 851
Pseudo-Aristotle 614–15
Pseudo-Avicenna 876
Pseudo-Bradwardine 559
Pseudo-Democritus 856
Pseudo-Euclid 616–17, 621, 627–8, 644–5, 648–9, 670
Pseudo-Ibn Māsawayh 979, 983
Pseudo-Ibn Sarābiyūn 984
Pseudo-Khālid 862, 874
Pseudo-Nemorarius 555–6, 564
Pseudo-Ṭūsī 462, 469–70, 493
Ptolemy 3–10, 13–17, 18–19, 21, 23–6, 28–34, 35, 37, 39–41, 44–46, 48–50, 52–5, 55–6, 59–126, 141, 160, 188–90, 192–3, 195, 199, 253–5, 257, 259–60, 264–8, 274, 277–81, 284–6, 289–95, 298, 300, 305, 391, 438, 445, 448, 464, 476, 478, 483, 489, 497, 499, 511, 524–5, 536, 554, 612, 643–4, 651, 655, 657, 659–60, 663, 665–7, 669, 674, 680, 702,

705, 708, 718–21, 723–4, 726–8, 785, 796, 807, 855, 872, 986, 993, 997, 1003, 1031
Puig, R. 272, 274–5
Pythagoras 343, 433, 495, 510, 520, 551, 847, 854, 860–1, 865, 869–70, 874, 883
Pythagoreans 268, 470, 721

al-Qabīṣī 279, 283
Qāḍī-Zāde 1004–5
Qalā'ūn, al-Manṣūr Sayf al-Dīn (Mamlūk ruler) 930, 1000
al-Qalaṣādī 270, 272–3, 275
al-Qalqashandī 807, 991, 997
Qāsim ʿAlī Qāyinī 153
Qāsiyūn (Mount) 8, 964, 970, 993
al-Qazwīnī, Ḥamdallāh al-Mustawfī 139, 200–1, 763, 808, 850, 1003
al-Qifṭī 20, 55, 457, 464, 540, 857, 860, 988, 991, 994, 1028
al-Qubayṣī 409
Qudāma b. Jaʿfar 800, 802, 807
al-Qūhī, Abū Sahl 10, 58, 360, 372, 425, 427, 458–9, 475, 481, 619–20, 623–5
al-Qushjī, ʿAlā' al-Dīn 59, 123–5
Qusṭā b. Lūqā 21, 23, 25, 55–6, 356, 397, 552, 617, 621–2, 644–9, 651, 655, 669–70, 912, 966, 982
Qusṭūs 261, 816
Quṭb al-Dīn: *see* al-Shīrāzī

Raban Maur 284
Rabelais, F. 872
Rabīʿ b. Zayd (Recemund) 250–1
Raḍī al-Dīn al-Raḥbī 931
Ragep, F.J. 126, 184, 304
al-Rahbī 1001
Ramelli, A.779
Raoul of Liege 573
Raqqa 9, 24, 46, 510, 999
Rashed, R. x, xiv, 18 n. 2, 48, 57 n. 49, 371, 373, 414–17, 425, 444–6, 481, 546, 572, 576–9, 669–71, 707–8, 711, 714–15, 728, 1022, 1025
Raspe 889
Raymond of Marseilles 285–7, 892
Rayy 10, 11, 49, 51, 52, 190, 398, 513, 823, 835, 865, 913–17, 921, 935, 948, 985, 990, 992–4
al-Rāzī, Abū Bakr Muḥammad Ibn Zakariyyā (Rhazes) 74, 619, 638, 683–5, 707, 710, 718, 818, 859, 867–9, 873, 877, 892–3, 896, 899, 900, 912–19, 921, 935, 937–8, 941, 943, 945, 948, 954, 957, 964, 970–2, 974–5, 978, 982–4, 992
al-Rāzī, Fakhr al-Dīn 882, 884
Regier, M.H. 188
Reginerus 553
Regiomontanus 266, 295, 496, 509, 560, 568, 579
Reitzenstein 898
Renan, E. 277, 1028
Renaud, H.P.J. 271–2, 275
Renouvier, Ch. 1029
Rheticus 299, 304–5, 496
Rhodes 191–2
Ribera, J. 248, 270, 274
Ricart, A. 974
Richard of Fournival 574
Richard of Middleton 295
Richard of Wallingford 555
Richards, R.J. 706–7
Richter-Bernburg, L. 194, 259, 274, 277
Riddle, J.M. 959
Riese, A. 570
al-Riqūṭī, Muḥammad 270
Ritter, J. 850
Robert 889–90
Robert of Chester 285, 287, 552, 562–3, 889; of Ketton 894
Roberts, V. 127, 305
Robertus Anglicus 794
Robertus de Marisco 553
Roberval, G. 558
Rodgers, R.H. 248
Roger II of Sicily 199, 809
Roger of Hereford 288
Romano, D. 279
Rome 797, 907
Rome, A. 445
Romuald Salernitanus 969
Roomen, A. von 454
Rose, V. 899
Rosen, F. 578
Rosenfeld, B. 169
Rosenthal, F. 55, 708, 712, 957–8, 1023
Rosinska, G. 281
Rouanet 597, 612
Rozhanskaya, M.M. 621–2, 627, 634
Rudolff, Chr. 415, 492, 570
Ruffini-Horner 363, 367, 383–4, 387
Rufin of Alexandria 983
al-Ruhāwī, Isḥāq b. ʿAlī 938
Rukn al-Dawla (Buwayhid ruler) 916
Ruska, J. x, 193, 859, 869–70, 873, 875–6, 878–9, 889, 896, 898–902
Russell, G.A. 709–10

Sabra, A.I. 126, 266, 305, 707, 710–15, 728, 1007
Sābūr b. Ardashīr (Buwayhid vizier) 990
Saccheri, G. 467–70, 493
Sacy, S. de 852
Ṣadr al-Sharīʿa 99, 108, 112, 122–3, 125, 127
al-Safāqusī 139–40

Ṣafī al-Dīn 589, 604, 607, 609–11, 613
al-Ṣāghānī 372, 481
al-Sahlī, Abū al-Ḥasan 879
Saʿīd b. ʿAbd Rabbihi 247
Ṣāʿid al-Andalusī 254, 256–9, 274, 986, 1029
Saʿīd b. Khafīf al-Samarqandī 160
Saladin: *see* al-Nāṣir Ṣalāḥ al-Dīn
Ṣalaḥ al-Mahdī 590, 594
al-Sālār, Ḥusām al-Dīn 468, 483
Ṣāliḥ Efendī 183
Salerno 554, 888, 965, 968–9
Saliba, G. 87, 103, 108, 126–7
Samanids 373
Sāmarrā 9, 988
Samarkand xi, 14, 155–6, 452, 530, 532, 754, 783–4, 999, 1002–5
al-Samaw'al xi, 356–8, 378, 381, 383, 387–90, 392, 397, 401–2, 417, 532, 546–7, 572
Sambursky, S. 706–7
Samsó, J. 244–5, 249–50, 255, 259–60, 265, 270, 272, 273–4
Samuel b. Judah of Marseilles 279–80
Sanad b. ʿAlī: *see* Sind
Sanchez Perez, J.A. 272
Saragossa 244, 254, 257–8, 270
al-Sarakhsī, Abū al-ʿAbbās 395
Saray 480
Sarfatti, G.B. 279
Sarjīs b. Hiliya al-Rūmī 816
Sarton, G. 264, 577–8, 1028
Sasanids 8, 581, 758–9
Savage-Smith, E. 957
Savasorda: *see* Abraham bar Ḥiyya al-Ṣaydanānī 353, 571
Sayili, A. 13, 14, 19, 264, 370, 993–4, 1007
Sbath, P. 669, 850
Schacht, J. 958
Schamp, J. 901
Scheubel, J. 562, 565, 578
Schipperges, H. 570
Schmidt, W. 445
Schmuker, W. 851
Schoonheim, P.L. 901
Schoy, C. 151–2, 156, 169, 537
Schrader, W.R. 575
Schramm, M. 54, 711–15
Scot, Michael 294, 729, 894, 896, 899, 900, 975
Scotus, Duns 295
Sédillot, J.J. ix, 14, 162, 169, 177, 538
Sédillot, L.A. x, 57, 162, 169, 177
Seljuks 995
Serjeant, R.B. 257
Servet, M. 979
Seth 862
Severus Sebokht 333, 785
Seville 248, 257, 261, 265, 271, 846
Sextus Empiricus 1021
Sezgin, F. 283, 570, 578, 816, 850–1, 853, 864, 883, 897, 899, 1028
al-Shādhilī, Sadaqa b. Ibrāhīm 950
Shāh Ḥusayn 151, 153
al-Shahrastānī 1028
al-Shahrazūrī 358
al-Shammāsiyya 8
Shams al-Dawla Abū Ṭāhir (Buwayhid ruler) 921
al-Shannī 360
Shāpūr I 758
al-Shaqūrī 972
Sharaf al-Dawla 10, 11, 51, 994
al-Sharafī, ʿAlī b. Aḥmad 195
Shawkat, I. 185
al-Shayzarī, ʿAbd al-Raḥmān b. Naṣr 940, 958
Shelomo b. Eliyahu of Saloniki 281
Shīrāz 50, 190, 610, 753, 759–60, 950, 992–3
al-Shīrāzī, Quṭb al-Dīn 14, 58, 96–9, 108, 112, 117–18, 120, 122, 125, 127, 266, 301, 462, 470, 950, 985, 996
Sībawayh 814
Siberberg, B. 815–16, 850
Sicily 566, 806, 820, 978
Ṣiddīqī 851
Siegel, R. 706–7
Siggel, A. 898
Sijistan 763
al-Sijistānī, Abū Ḥātim 817
al-Sijzī 159, 402, 405–6, 417–18, 476, 491, 502, 506
Silverstein, T. 899
Silvinus, P. 847
Simon of Castello 555
Simon of Genoa 979, 984
Simplicius 295, 431–2, 444–5, 464, 1024
Sinān b. al-Fatḥ 353, 354, 370, 371
Sinān b. Thābit 9, 18, 23, 941
Sind b. ʿAlī 353, 395, 571, 638
Sindbad 798
Singer, D.W. 9, 883, 899, 891, 900
Sisebut (King) 245
Smith, A.M. 728
Smith, D.E. 334, 570, 572
Snellius 659–60, 665–6
Sobhy, G.P. 264
Socrates 455, 854–5, 865, 869, 913, 1034
Solinus 716
Sonnedecker, G. 274, 957
Sorabji, R. 704–8
Souissi, M. 275
Souryal, S.S. 275

Spain 83, 191, 200, 244, 247, 252, 276, 279, 282–3, 305, 493, 517, 519, 540, 754, 759–60, 762, 764–5, 769, 775–6, 783, 788, 794, 804, 812, 872, 903, 925, 946, 997, 1006
Spink, M.S. 959
Stack, Th. 957
Stadler 898
Stapleton, H.E. 853, 860, 866, 870, 883–4, 900
Stavenhagen, L. 890, 899
Steele, R. 873, 891, 899
Steinschneider, M. 277, 283, 897
Stephanus of Alexandria 864, 889
Stephen of Pisa 982
Stern, S.M. 249
Stevin, S. 547
Stifel, M. 492
Stoics 675, 705–6, 721, 1021, 1032
Strange, Guy le 992, 1007
Strohmaier, G. 713
Sublet, J. 1007
Sudhoff, K. 899, 901, 969
al-Ṣūfī, ʿAbd al-Raḥmān 10, 19, 49, 50, 57, 993
Suhrāb 193, 201
al-Sulamī 358, 371
al-Sumaysāṭī 446
Su-Sung 271
Suter, H. x, 55, 127, 252, 255, 278, 415, 536
al-Suyūṭī 928
Swerdlow, N. 111, 122, 125–7, 265, 274, 305
Syracuse 418, 638
Syria 9, 46, 130, 133, 157, 162, 167–8, 179, 200, 270, 282, 333–5, 566, 754, 759, 765–6,775, 783, 785, 794, 826, 828, 832–3, 930, 932, 940–1, 954, 985, 1003

al-Ṭabarī, Abū Jaʿfar Muḥammad 1028
al-Ṭabarī, ʿAlī b. Sahl Rabbān 818, 912
al-Ṭabarī, ʿUmar b. Farrukhān 249
Taddeo Alderotti 971, 977
Taiz 179, 184
Tajaddud, R. 1023
Takahashi, K. 728
Talas, A. 996, 1007
Tallgren, A.M. 200
Tannery, P. x, 541, 573, 577
al-Ṭanṭāwī 166–7
al-Tanūkhī 358, 410
Taqī al-Dīn 14, 183, 380, 391, 669, 779
Tartaglia, Niccoló 549–50, 570
al-Tawḥīdī 857
Taylor, B. 368
al-Ṭayyibī 812
Teheran 10, 756
Terès, E. 248–9, 251
Terzioglu, A. 992, 1007
Thābit b. Qurra xii, 21–3, 26, 34–5, 37–46, 48, 54–8, 159–60, 169, 249, 259, 289, 292–3, 296, 299, 300, 304–5, 353–4, 360, 370, 409–10, 412–13, 417–19, 421–7, 444, 450–2, 455, 458, 464–7, 470, 473, 483, 489, 493–4, 501–2, 533, 552–3, 560, 576, 617–18, 620–2, 626–8, 634, 645, 817, 911, 914
Thales 470
Theisen 728
Theodoric of Freiberg xii
Theodorus 862
Theodosius 7, 18, 55, 448, 482–3, 560
Theon of Alexandria 7, 23, 268, 438–9, 445–6, 525, 643, 649, 652, 670, 708, 785
Theon of Smyrna 346
Theophilus 861–2, 887, 889
Theophrastus 262, 813, 817, 895
Theosebeia 857, 861
Thomas Aquinas 295, 556
Thompson 571
Thorndike, L. 270
Thucydides 1028
Tibbets, G. 211
Tiberius Caesar 716
Tideus 718
al-Ṭignarī 261–2
al-Tījānī 812
Timeus 857
Tīmūr 1004
Toledo 83, 248, 257, 259, 261, 265, 287, 542, 776, 794, 848, 872, 894, 970
Toomer, G.J. 77, 126, 259, 265, 304
Torres, E. 275
Torres Balbas, L. 262
Torricelli, E. 280
Tortuensis, Abraham 984
Transue, W.R. 538
Tripoli 179, 990
Trolle, D. 959
al-Ṭughrāʾī 854, 860, 873–4, 880–1, 900
al-Tujībī 861
Ṭūlūnids 992
Tummers, P.M. 575
Tunis 181, 184, 272, 820; Tunisia 270, 283, 784, 935
Turkey 162, 182
Ṭūs xii, 865
al-Ṭūsī, Naṣīr al-Dīn x, xi, 13, 14, 22, 58–9, 61, 70, 73, 93–5, 97–8, 114, 118–20, 122, 125, 127, 188, 280, 301–3, 338–9, 378–80, 383, 386, 389, 414–15, 461–2, 467–70, 483, 515–20, 527, 536, 555, 568, 573, 576, 667, 1002–3
al-Ṭūsī, Ṣadr al-Dīn 462

al-Ṭūsī, Sharaf al-Dīn xii, 272, 338, 362–71, 373–5, 381, 415, 450, 532
Tuulio-Tallgren, O.J. 200
Tycho Brahe 281, 296, 303

ʿUbayd Allāh al-Istijī 246
Ugo Benzi 971, 978
Ullmann, M. 709, 846, 850–2, 853, 882–5, 898, 957, 959
Ulugh Beg 14, 59, 281, 452, 530, 807, 1003–5
ʿUmar b. ʿAbd al-ʿAzīz (Umayyad Caliph) 157, 909
ʿUmar I (Caliph) 784
al-Umawī 341, 345–6, 348, 409, 417
Umayyads 760
Ünver, A.S. 184
al-Uqlīdisī 331–2, 334–6, 338, 340, 383, 389, 417, 546, 548–9, 571–2
al-ʿUrḍī 13, 14, 58, 85, 90–3, 97–9, 104–8, 110–17, 119–22, 125–7, 301, 1003
Urso 967–9
ʿUrwa b. al-Zubayr 909
ʿUṭārid b. Muḥammad 656

Vajda, G. 1007
Valencia 760
Valerian (Roman Emperor) 758
van Helmont 897
van Vloten, G. 1023
Vardjavand 13
Varron 846
Vasco da Gama 203, 209, 811
Vaverde, J. de 979
Vefā, Shaykh 183
Vernet, J. 56, 245–6, 249–50, 255, 265, 273, 304, 571
Verona 573
Viete, F. 496, 514, 517, 570
Viguera, M. J. 275
Viladrich, M. 255–6, 274
Villuendas, M.V. 258, 536
Vincent of Beauvais 873, 875, 899
Vindanios Anatolios of Berito 247 (of Berytos) 816
Vitruvius 476, 615, 775, 785
Vjatkin, K.L. 1004
Vogel, K. 335–6, 348, 415, 571, 579–80
Volger, L. 851
Voss, D. 126

al-Wafāʾī 168
al-Walīd I (Umayyad Caliph) 909, 934
Wallis, J. 469, 493
Walzer, R. 913, 957, 1023–4, 1033
Wang Ling 19
Wappler, H.E. 580
Wāsiṭ 999
Waters, E.G.R. 572
Weber, E. 1025
Weissenborn, H. 552, 573
Weisser, U. 850, 883, 899
Werner, J. 532
Wertheim, G. 579
Wibald 888
Widmann, J. 559, 570
Wiedemann, E. x, 19, 184, 619, 630, 669, 709, 715, 852, 882, 885
Wielgus, S. 901
Wiet, G. 1006
Wigandus Durnheimer 557
William of Auvergne 294
William of Conches 725, 965–7
William of Malmesbury 540
William of Moerbeke 556–7, 560, 575, 975
William of Ockham 723
William of Saint-Cloud 296–7
William of Saint-Thierry 966
Wilson, J. 408, 413
Wingate, S.D. 729
Winter, H.J.J. 669
Witelo xii, 470, 493, 555, 560, 721, 728
Wittich, Paul 532
Woepcke, F. x, 416, 536, 538, 568, 576, 579–80, 616
Wood, C.A. 714, 959
Wood Brown 901
Wüstenfeld, E. 1007
Würschmidt, J. 184

Xenophanes 870

Yahuda b. Solomon Kohen of Toledo 279
Yaḥyā b. Abī Manṣūr 9, 26, 250
Yaḥyā al-Ghazāl 249
Yaḥyā b. Isḥāq 247
Yaḥyā b. Khālid b. Barmak 934
Yaʿqūb b. Ayyūb 272
Yaʿqūb b. Ṭāriq 20–1, 33, 54–5, 158
Yāqūt 139, 808–10, 820, 851, 989
Yazdegerd III 8, 16, 253
al-Yazdī 358, 380, 391, 401–2, 407, 410, 415
Yemen 133, 137, 179, 200, 257, 753, 783, 836
Youschkevitch, A. 424, 444, 571, 577–9
Yūḥannā b. Yūsuf 355, 638

Zadith, Senior 870, 893 (= Muḥammad Ibn Umayl al-Tamīmī)
al-Zahrāwī, Abū al-Qāsim Khalaf b. al-ʿAbbās 252, 256–7, 262, 264, 274, 818, 920–1, 943–8, 959, 970, 983–4
Zalzal, Manṣūr 599–600, 602–6, 609–10
al-Zanjānī 401
Zarlino, G. 585, 596, 605, 610, 613

al-Zarqāllu 15, 31, 83, 198, 245, 254, 257–9, 265, 267–8, 270, 273–4, 283, 286–7, 296, 298–300, 794
Zayn al-ʿArab al-Miṣrī 932
Zeki Pacha, A. 1000
Zenodorus 437–9, 445
Zoroastra 858
Zosimus of Panopolis 856–8, 860–3, 874
Zotenberg, H. 616
al-Zuhrī 809

# 2. Subject index

abacus (*takht*) 334, 539, 544, 551, 570
aberration: spherical 664, 666
abscissa 487
*adab* 797–800, 802, 807–8, 905
addition 332, 335–7, 545, 548–50
*adiectio* 578
agriculture 244, 262–3, 813–5, 841–50; management of an agricultural enterprise 841–2, 849
agronomy 247, 257, 261–3, 272
alchemy xi, 845, 853–97, 909, 914–15, 1020
*alcho(a)rismus* 544
algebra xi-xii, 349–81, 388, 395, 397, 401, 406, 418, 448–50, 492, 540, 561–3, 565–6, 568–70, 572, 576, 642, 1013, 1016, 1020–1; application to geometry 376; arithmetization of 356–59, 376
algebraic: calculation 352–6, 397–8, 565; equations 353–4, 356, 358, 361–2, 395, 450; geometry xii; irrationals 362; methods 353, 450; number 390; operations (transposition and reduction) 352; power 357, 398
algebraists (*aṣḥāb al-jabr*) 353, 376, 378, 389, 410, 413, 488
algorism 540, 544–5, 547–8
*algorismus* 544
algorithm 352, 359, 367, 381–4, 386, 397, 520, 529–30, 568, 668; Horner 387; of the solution 350–1
almanacs 3, 260
*almucantar* 481
amputation 909, 945
amulets 936, 953–4
anaclastic 652; curves 660
analemma 500, 533
analgesics 909, 923–5, 943, 945, 950; *mukhaddir* (analgesic) 923–4; *takhdīr* (analgesia) 923
analysis: combinatorial 376–80, 412, 414, 452; Diophantine 563; indeterminate 352–5, 394–407, 414; integer Diophantine 376, 401–8, 414; numerical 376, 381–94, 418; rational Diophantine 354, 357, 394–401, 414; and synthesis 405–6
anatomical illustrations 952
anatomy 673, 686, 689, 919, 921, 932, 950–2, 969, 977, 980; functional 691; ocular 661, 673, 680, 683–5, 690, 697, 704, 717, 965
anesthesia 943
angle: congruent 460; of deflection 675; of deviation 393, 665, 668; hourly 499, 535; of incidence 393, 665–6, 668, 675, 682, 687, 720; of rebound 675; 682; of reflection 687; of refraction 665; *see also* trisection
antisepsis 943
*anwā'* 2–3
*apices* 540
apogee of the sun 30–1, 291
apotome 355, 370
approximation 332–3, 382–3, 385–9; conventional 383, 385–6, 389; of equations 362, 367; of fraction 357; irrational square root 546; methods 418; of *n*th irrational root of an integer 388; of *n*th root of an integer 390, 568; of $\pi$ 420–1, 573
Arabesque code (music) 589–92
arboriculture 824, 828, 847
arc: difference (*qaws al-khilāf*) 393; formulae of 495; of visibility (*arcus visionis*) 34, 44–5
Archimedean: screw 771; spiral 455, 486
area 333, 563, 567–8, 577; of circle 420, 425, 434, 439, 449–50, 452, 551, 559, 573; of cone 559, 576; of curved surfaces 419, 431; of cylinder 576; of disc 441; of ellipse 472; of lunules 434; of parabola 426; of parallelogram 422; of pentagon 438; of polygon 421, 439, 441–2, 449–50, 452; of polyhedron 440–4; of pyramid 439, 441, 443, 449, 452; of quadrangle 452; of segment of circle 449; of segment of parabola 421–2; of solid 431; of sphere 421, 439, 451, 559; of triangle 449–50, 452, 474, 559

arithmetic 331–48, 352, 376, 383, 386–7, 408, 427, 449, 456, 492, 540–1, 543, 547, 553, 561, 570, 572, 577, 1009–10, 1012, 1015–18, 1021–2; commercial 569; decimal 382; games 414; Hindu 331, 334–8
arithmetical: algebra 356; operations 354; operations on monomials and polynomials 357; triangle 378–80, 386, 414; *see also* means
arrangements 377, 380
artifacts: medical 906
arts: liberal 1015
astrolabe 205, 265, 272, 285–6, 475, 478–82, 484, 493, 554, 767–9, 785, 792–4
astrology 1, 8, 15, 245, 282, 500, 855–6, 895, 953–5, 1020
astronomers, methods of 331, 391
astronomical: Greek sources 3–7, 21–3; Indian and Persian sources 8, 20–1; observation xi, 767; observatories 8–14; *see also* instruments, tables
astronomy 381, 393, 420, 500, 542–3, 796, 818, 895, 1009–10, 1013, 1016, 1018–20, 1022; Copernicus and Arabic astronomy 298–303; Copernicus and Ibn al-Shāṭir 111–14; folk 132–4; physical 3, 7, 17, 80–2, 85–7, 266–9, 294–6; practical 15–17; Ptolemaic (critical analysis) 25–34, 59–61, 74–83, 265; spherical 495
*auere* 567, 579
augmentation (*jamʿ*) 331
*augmentum* 578
automata 785, 788
axis: of constraint 628–9; of equilibrium 628–9; of suspension 629; of turning 628–9

balance 634; 1013, 1020; hydrostatic 617; 'of wisdom' 635–7, 640; soil 635; water 635; 638; *see also* humours
*Bayt al-ḥikma* (House of wisdom) 9, 193, 349, 351, 540, 910, 986–90, 993
*bericuocolo* 573
binomial: coefficients 378; equation 373; expansion 357; formula 356, 384, 386; of second degree 362; of third degree 362
binomials 350, 354, 357, 371
biquadratic problems 354
blaze (embrasement) 660
blind (Venetian) 550
bloodletting (*faṣd*) 920, 928, 942
body: biconvex refractive 695; floating 631–2; physical properties of a heavy 620, 628; three-dimensional 642
bonesetters (*mujabbirūn*) 940
bonesetting (*jibāra*) 920, 942, 947
botany 244, 261–3, 271, 813–19, 821–41, 846, 849–50
bread 829–33, 844
bridges 761–4
building construction (materials) 764–6
burning: glass 720; *see also* instrument, mirror, sphere
bushes 841, 849; fragrant 822–4

caesarian sections 944
calculation: of arrangements, combinations, permutations, substitutions 377; auxiliary 357; combinatorial 378; curved areas and volumes 418; of finite differences 394; of the frequency of letters 377; of infinitesimal areas and volumes 418–31; prostapheretic 496; rules for fractions 354; spherical 497, 499, 509, 511–12, 515; trigonometric 527
*calculus* 551
calendars 16–17, 229–30, 250–1, 1020
cartography 191–201, 480; atlas of Islam 194; al-Bīrūnī's mapping 194–8; Hellenistic 191–3; al-Idrīsī 199; Iranian 200; Isfahan world-map 150–3; al-Ma'mūn's map 193–4; Marinus 192; nautical map (chart) 220–2
castration 946
cataract 965; couching 949–50; removal 949
catoptrics 644–6, 648–9, 652–3, 655–6, 661, 674
cauterization 944, 946
cautery 920, 928
*census* 562, 567, 577–9
centre: of gravity 419, 614–15, 617, 619, 621, 626–9, 642; of the Universe 619–22, 628
cereals 815, 829–31, 843–5, 848–9
charlatans 937–8
chart: *see* cartography
chemistry 868
chessboard 550
chord of $1^{\circ}$ 75: mother 522; of the double arc 495; *see also* table
chronologies 905
circle 460, 474, 558; area of 420, 425, 434, 439, 449–50, 452, 551, 559, 573; 'extreme' property of 439; of azimuth 479; quadrature 432; reference 497; sector of 432, 434; squaring 455
circumcision 947
cissoid 455
classification of plants 262, 814–16, 846
classification of sciences 813, 1008–25
climatology 818
clinical: cases 916; training 936
clock (mechanical) 794–5

coefficient: binomial 378; integer 384; of expansion (tables) 357; of the first power of the unknown 358
colour 644, 655, 663, 668, 675, 677–8; fabrication 889; royal 889; theory of 722
*columna* (*rotunda*) 576
combination 377, 379, 380, 411
combinatorial: analysis 376–80, 412, 414, 452; interpretation of arithmetic triangle 378–9; methods 410; rules 381
commercial transaction 349
compass 222–4, 359, 454–5, 484, 892; perfect (*birkār al-tamm*) 458, 460
conchoid 455; of a circle 558
cone 425, 427, 450–1, 559, 576, 647–9, 1017, 1019; area and volume of 439, 559, 576; circular 450–1, 476; frustum of 425, 427, 439; truncated 451–2; visual 651, 725, 727
congruence 407; linear 413–14, 568; system of 413
congruent: angle 460; numbers 402, 405
conic section 359, 371, 420, 452, 455, 458–9, 475, 481, 486, 488, 558, 560, 656
*consideratio* 566
construction: geometric 448, 450, 454, 456–9, 483–5, 494; plane geometrical 364; of a positive root by the intersection of two conics 360; with a ruler and compass 359, 454–5, 460; spatial 457
contraction 472–3, 475
co-ordinates 486–90, 500; ecliptic 512; equatorial 512; fixed stars 50; oblique 486; polar 486, 489; rectangular 486, 489–90
cornea 914–15
cosecant 514
cosines: law of 484, 486
cosmogony 438, 857
cosmography 438, 818
counter 540, 570
couple of al-Ṭūsī 94–5
cryptography 377–8, 414
crystal 657–9
cubatures 448, 450–1
cube 359, 371, 376, 456, 458; Christoff 492; multi-dimensional 492; of an integer 386
cubic: equation 338, 359–60, 362, 364, 367, 369, 372, 375, 400, 450, 452, 456, 565, 579; number 401, 404; root 373, 374, 401
cuppers (*ḥajjāmūn*) 947
curves 361–4, 369, 391, 429, 455, 486–7, 656, 668; conical 360, 362; continuity of 363; convexity of 363; of genus zero 397; intersection of 360, 363–5, 450; second degree 363, 397; third degree 455
cylinder 451; area 576; circumscribed 427–9; inscribed 427, 429; oblique 425; sections of 421, 425, 429; straight 425; volume of 428–9

dams (construction of) 753, 757–61, 783
Darboux sums 429, 431
date palms 815, 820, 825–6, 838–9
decagon 525
decimal: fractions 336, 338–41, 389–91; integers 390; scale 334, 336; sign 340; system 331, 390, 454
decomposition (into prime factors) 410
deflection 675, 682, 685, 687
degree: of passage 497, 499; of rising and setting 497
denominator 340, 545–6, 572
density of the 'cosmos' 621
deontology 938
derivative: equation 368, 369; function 365; of a polynomial 369
dialectic 1018, 1025
diameter, apparent 652; *see also* moon
dihedron 653
dilatation 473
diminution (*tafrīq*) 331; *diminutio* 578
Diophantine: equations 394–5, 407, 565, 580; problems 395, 564; solutions 356, 404; *see also* analysis
dioptre 660; spherical 661, 666
dioptrics 656, 660–1
*dirham* 333, 577
disc 441; area of 441
discriminant 358, 363
dissection, anatomical 950–1
divination 953–4
divisibility (of integers) 408
division 332–3, 335–7, 390, 548–9, 571; by two of odd integers 388
drachm 568; *drachma* (or *dragma*) 577–8
dream interpretation 954
dropsy, abdominal 944
duplation 335–6, 340
dustboard 337–9
dynamics 614, 642; dynamic principle 618

earth: meridians 188–9; rotation 52; size 187–8; terrestrial latitude 186–7; terrestrial longitude 190–1
eclipses 47, 77, 499, 505
*eidolon* 674–5, 677–80
elements (the four) 967
elimination (algebraic technique) 356
elixir 853, 860, 866–8
ellipse 458–9, 472–4, 486, 660; area of 425, 472
emanation, Neoplatonic principle of 678
emanationist metaphysic 721–2

emission 651, 674–5, 677–8, 681–2
energy 794
engineering: civil 751–69; mechanical 769–95
enneagon 528–9
equality: of areas 351; double 400
equation: binomial 563; of a circle 363; concept of 350; compound 373; of degree ⩽3 360, 363–4; Fermat's 401; of first degree 350, 360; of fourth degree 403, 450; with irrational coefficients 354; Kepler 530; numerical 363, 367, 369, 373, 381–2, 568; of a parabola 363; polynomial 363–4; with positive rational coefficients 352; quadratic 359, 363, 449, 450, 452; of second degree 350, 353–4, 360, 363, 561; with a single unknown 352; theory of 349, 353–5, 360–3, 369; of third degree 360, 362–3; trinomial 350, 353, 362, 562–3, 578; *see also* algebraic, cubic, derivative, Diophantine, linear, table, theory
equilibrium 615–17, 619, 622, 626–30; laws of 614; of bodies in liquids 615; of a lever 627–8
erasement 545, 548–50, 572
examination of physicians 941
exhaustion, method of 419–20, 423, 429, 474
existence: of a circle 432; of a finite decomposition 410; of a limit 441; of geometric figures 462; of lines 462–5; odd perfect numbers 412; of point of intersection of two curves 364; of points 462; of poles 392; of positive solutions 363; of quadrable lunules 435; of rectangle 465; of roots 357, 363–4; of solids 463; of square 433; of surfaces 463; of transcendent ratio 433
expansion, formula of binomial 357
extraction: of a cubic root 358, 382–6, 451, 568; of *n*th irrational root 388; of *n*th root 383–4, 386–9; of numerical root 336, 568; of root 382, 386, 452; of a side for all powers 390; of square root 332, 336–7, 355, 382–6, 390, 398, 544
extramission (theory of vision) 717, 725–8
*extrema* areas and volumes 418
eye: anatomy 661, 673, 680, 683–5, 690, 697, 704, 717, 965; description of 656; diseases 911, 950; entropion 950; evil 907, 928, 953; pannus 950; therapy 914–15; trachoma 950; trichiasis 950

factor, prime 410–11
factorization (method) 411
faculties, three 920
Fermat's theorem 404
fever (definition of) 976–7
figures, plane 438, 440–1, 450–1
fingers 213–16
*fiqh* 1014–15, 1023
fixed stars 10, 26, 46, 50, 488; acronycal setting 2, 3, 7, 24; apparent colours 50; catalogue 10, 47, 50, 56; ecliptic co-ordinates 50; heliacal rising 2, 3, 7, 24; magnitude 50; precession 29–31
flowers 815, 821–3, 846
force (*virtus fortitudo*) 617, 619–22; Archimedean 640; buoyancy 631
fountains 785
fraction 333, 338, 541, 561, 571; composite 336; decimal 389–91, 415, 546; *munṭaq* 333; ordinary 336, 338–41, 415, 544–5; sexagesimal 336, 415, 544–7; *ṣumm* 333
fruit 815, 818–20, 823–8, 834, 838, 840, 844, 848
function: affine 393, 668; auxiliary 500, 509, 512; circular 497; continuous 424, 428; cotangent 392; elementary arithmetical 408–13; monotonic 429; multiplicative 411; polynomial 365, 393, 668; rational 396; tangent 496

gears 789
*gelosia* 550, 573
generation (theories of) 975–6
geodesy 186–91, 484
geographical co-ordinates: *see* earth
geography: 796–812; sacred 135–41
geomancy 953–4
geometric: construction of roots 363; interpretation of algebraic procedures 353
geometrization of algebra 359–62, 376
geometry 352–3, 360, 447–94, 505, 540, 542, 551, 554, 559, 560–1, 566, 573–4, 577, 1009–10, 1012, 1015–20, 1025; descriptive 500; elliptic 466, 469–70; hyperbolic 466, 469–70; Lobachevskian hyperbolic 461, 465; metric 352; plane 448, 483; spherical 482–5; three-dimensional 492
geoponic 813, 816
gnomon 480, 489, 499, 510
gnomonics 513
grafting 823, 829, 834, 838, 845, 847
*graticola* 550
gravity: of bodies 620–1; centre of 419, 614–15, 617, 619, 621, 626–9, 642; concept of 619–23
gynaecology 947–8

*ḥadīth* 905, 928, 930
haemorrhoids 946
halo 644, 656

harmony 1010
hay fever 916
heptagon: regular 360; side of 372
hernia, umbilical 945
Heronian formula (area of a triangle) 559
hexagon 451, 524, 536
Hindu, system 331, 333–4
*ḥisāb al-hindī* (Indian reckoning) 540, 544, 570
*ḥiyal* 456, 632, 1013, 1016–17
Holderien comma 589–92, 596
homothety 472–3, 475
horizon 497
horoscope 497
horticulture 847
hospitals 248, 905, 908, 914, 933–6, 939 ʿAḍudī 914, 917, 931, 936, 955, 991–2, 999–1001; *bīmāristān* 934, 1001; Damascus 934; Manṣūrī 930, 932, 934–5, 1001; *māristān* 934; Nāṣirī 930–1, 934; Nūrī 930–1, 949, 955, 991; Ottoman 935
humoral pathology 912–13, 919
humours 967; balance of (*iʿtidāl al-mizāj*) 912; imbalance of (*khārij ʿan al-iʿtidāl*) 913; theory of 252, 262, 967
hydraulic mechanisms 1013, 1020
hydrology 849
hydrostatics 615, 618–19; Archimedean 630–1; science of 642
hyperbola 360, 362, 458–9, 473, 486, 557, 656, 659; equilateral 360, 473, 475
hyperboloid 660; volume of 431
hypersphere 492
hypotenuse of the triangle 510
*hypothenusa* 574

identities: geometric interpretation of 490; quadratic 490; stereographic interpretation of 491
illustration 906
image: inversion 698, 704; projected 672, 687, 695, 698–9; theory of ocular 673
imbalance of humours 913
impact, mechanical 698
incidence: angle 393, 665–6, 668, 675, 682, 687, 720; point of 651, 663
inclination: *mayl* 620; 'natural' 628; νεύσεις 557–8; ῥοπή 614–15
indeterminate analysis (*al-istiqrāʾ*) 352, 353–5, 394–407, 414
induction 408; complete finite 357, 405; infinite descent, method of 407
infinitesimal: areas and volumes 418; calculations 450; determinations 418–31; methods 448, 450–1; techniques 642
infinitesimalists xii
infinity 378–9
ingenious devices: *ʿilm al-ḥiyal* 618, 632, 785–95; toys 785; *see also ḥiyal*
inheritance 349, 352–3, 394
instruments: astronomical 8–17, 256, 448, 459, 475, 751, 785, 789, 1013; astronomical compendia 168; burning 656, 660–1; computing 792; musical 1013; nautical 212–29; optical 661–2, 1013; surgical 906, 920, 946, 948–9; surveying 751, 766–9
integer 382–6, 388–9, 403, 541, 544, 546, 548, 561, 579; decimal 390; multiplicative properties of 408; natural 404, 414; positive 402; sexagesimal 387; solutions 402, 404
integral 429, 431; Cauchy-Riemann 429; Riemann 423–4; sums 419, 424–5, 427, 429, 626
interpolation 382, 391–4, 523, 668; function 381, 511, 529; linear 332, 393, 391, 524–8, 537; parabolic 391; quadratic xi, 392, 528
intersection: of conical curves 360; of curves 363–5; of semi-parabola 360; of two conics 360, 362
intromission 651, 662, 680, 682–3, 685, 725–7, 965
inversion 472–3
*iqlīm* 797, 803
irrationalities: cubic 452, 455; quadratic 448, 452, 455
irrigation 752–64, 769–70, 774, 849; basin 752; perennial 752–3, 757; terrace 752–3; wadi 753, 757–8
isepiphanies 439–40, 444
Isidorian culture 244–7
isocahedron 443–4
isoperimetric problem 418, 437–44

*jabr wa-l-muqābala* 355, 370, 416, 529, 537, 561, 563, 579, 639–40, 639–41, 1013, 1020
*jidhr* 577
*jughrāfiyā* 796; *see also* geography

Kaʿba (orientation) 129–30
*kalām* 1014–15, 1023, 1025
*kamāl* 228–9
*khashabāt* (woods) 225–8
kind (*gens*) 617
kinematics xii, 614–15

language (science of) 813, 1012, 1015, 1019, 1025
Latin–Visigothic tradition 245
law: of arithmetic 350, 352, 356; of cosines 484–5; of deflection 674; of equality of angles 677; of equilibrium 614; 682;

law: (*continued*)
of inverse return 659, 665; of reflection 647, 663, 720, 728; of refraction 665, 720, 724, 728; of sine 484; of Snellius 660, 665; *see also* lever
lemma: of Archimedes 360, 370, 372; of al-ʿUrḍī 106–7
lens 657–9, 691–4, 698, 704; biconvex 656, 659, 666; burning 656; crystalline 727; hyperbolic 660, 666; plano-convex 656, 659–60; spherical 660–1, 666
lever 634; axis of rotation 620; beam 617; law of 615–16, 619, 622, 626–30, 632; ponderable 627; stationary balanced 614–15
lexicography 377, 813–4
light 673, 678, 684–5, 687–9, 704, 718–20, 722; geometrization of 719; nature of 717, 723; propagation of 660–3, 717, 719 (accidental 720; rectilinear 677, 681–2, 686, 719–20; reflected, refracted 663, 719–20); theory of 661, 722, 728
linear: congruences 413–41; equations 395, 397, 569, 639; equations with several unknowns 354, 357, 378; interpolation 393, 391; intersection 484
lines, polar 473
linguistics 377–80
lithotomy 946–7
*līthūrghas*, stupor 917
load: commensurable 616, 627; incommensurable 627
logarithm 496, 524
logic 1010, 1012, 1014–18, 1020
*lumen* 722–3, 725
luminous phenomena 660
lunar theory: Ibn al-Shāṭir 100–3; prosneusis 76; Ptolemy 62–4; Quṭb al-Dīn al-Shīrāzī 96–100; al-Ṭūsī 93–5; al-ʿUrḍī 91–3
lunules 418, 432–7; area of 434; quadrable 435–6
*lux* 722–3, 725

machine, simple 632–4
*madrasa* 248, 936, 939, 998–1000, 1005
magic 880, 953, 955; bowls 906, 954; square 414, 561; sympathetic 928, 954; talismanic 249
magnitude (*magnitudo*) 617
*māl* 567, 577
*mamlakat al-Islām* 801–6, 809, 812
mandrake 924
manure 821, 843, 848–9
*maqām* 582
*materia medica* 922, 963
mathematics 244, 248, 258, 271, 276–7, 679, 1010, 1012, 1014–16, 1018–20; Hindu 346; of light and vision 718–20; recreational 569
maximum 365–8, 418; and minima of polynomials 369; of a third degree polynomial 369
means: arithmetical 454; two 360, 420, 451, 455
measles 914–16, 923, 980
*mechane* 614
mechanical: devices 456, 614; movement in geometry 470–5
mechanics 260, 420, 456, 616, 619, 622, 642, 680, 1016, 1021; optical 698
mediation 335–6
medical: sciences 813; training 939, 941–2
medicine 244–5, 248–9, 261–2, 271, 276, 856, 895, 903–84, 1011, 1017–20, 1022; definition of 968; Indian 912–13; Persian 913; pre-Islamic 927–9; prophetic (*al-ṭibb al-nabawī*) 927–30, 938; Ṣafavid 943; subdivision into theory and practice 968–9; university teaching 969–71
medium 666, 668, 695, 722, 727; material 630–1; notion of 657; opaqueness 657, 665; refractive 665; transparent 662, 677, 687–8, 698
melodies (science of) 1018
meningitis 917
Mercury: Ibn al-Shāṭir 120–2; latitude 72–3; Ptolemy 65–7; al-Qushjī 123–5; Quṭb al-Dīn al-Shīrāzī 118–20; Ṣadr al-Sharīʿa 122–3; al-ʿUrḍī 115–17
mesh 550
metal: *see* transmutation
metaphysics 380, 1010, 1014, 1016, 1019–21, 1024
meteorology 718, 849
method: of Archimedes 420, 427, 451; converging iterative 454; interpolation 382, 391–4, 523; monomial 392; *sankalt* 392; *see also* exhaustion, infinitesimal, Ruffini-Horner
midwives 947
mills 783–4, 789
minute 336, 545
mirrors 674–5, 677, 682, 685, 687, 895, 1013, 1020; burning 457, 644–9, 652–3, 655–6, 661, 663, 667, 720, 1013; concave 646, 648, 652–3; conical 663; construction by points and tangents of a parabola 654; construction of 652, 654; convex 646, 652; cylindrical 663; ellipsoidal 655–6; entertaining 649; parabolic 656, 667; plane, spherical 646, 652–3, 663
monomial 357, 363; method 392

moon: apparent diameter 42, 47–8, 56; visibility 16, 32–4, 40–6, 53–4; latitude 67–8; *see also* lunar theory
morals 1010, 1017, 1019, 1024
*Moriscos* 243
morphology (of plants) 814, 816–17, 839–41, 845
motion: atomist idea of 678; of bodies 630–1; on an eccentric 35–7; mechanical 614; natural 614, 620, 628; theory of 617, 619
movement: of a perpendicular 466; 'simple' 465–6
*Mudéjares* 243
*muḥtasib* 766, 940, 942
multiplication 332–3, 335–7, 340, 487, 544–5, 548–50, 571–2
multiplier 571
*muqābala* 355, 370, 410, 529, 537, 561, 563, 579, 639–40, 1013, 1020
music 248, 420, 581–613, 914, 1009, 1017, 1018, 1020, 1022
*mutaṭabbibūn* (medical practitioners) 918, 925
*muwaqqit* 176–7

nadir 488
nautical: accuracy of course 232–6; instruments 212–29; routes 204–5
navigation (science of) 895
necromancy (science of) 895
nephritis (acute) 916
Newton: formula 528; method 367
non-naturals 920–1
*noria* 774–5
normal form, notion of 350, 352
nourishment (plants) 818, 840
number: abundant 417; aliquot parts of 409, 411; amicable 409–10, 412–13; composite 410; congruent 402, 405; cubic 401, 404; deficient 417; equivalent 413; even 342, 412; figurate 379, 380, 410–12; irrational 355, 357; natural 854; odd 342–3, 412; pentagonal 344; perfect 412–14, 417; polygonal 341–2, 344–6, 414; prime 408–11, 411, 413, 417; pyramidal 644–6; rational 355, 387; rational positive 350; real 387, 390, 421; sexagimal 451; square 344, 421; (science of) 1012, 1020; successive odd 425, 427; theory 331, 376, 854; triangular 343–4
numerals (Indo-Arabic) 332, 335, 539, 542–3, 570–1
numeration 331–2, 544
numerator 333, 339–40
numerical: algorithms 381, 382; analysis 376, 381–94, 418; equations 288, 363, 367, 369, 373, 381–2, 568; triangles 402–3, 405
*numerus* 577–8

oblique ascension 497
obliquity of the ecliptic 11, 24, 74–5, 497
observation tube 10
observatory 8–17, 519, 992–4, 1002–6
octahedron 443–4
oculists (*kaḥḥālūn*) 940
olive tree 824–5, 827, 830, 838–9, 840–1, 845, 847
oniromancy 1020
ophthalmology 644, 932–3, 949–50, 965
opium 924
optics 381, 555, 575, 673, 679, 680, 686, 726, 966, 1016, 1021; geometrical 643–71, 720; Hellenistic 643–4; meteorological 661; physical 644–5, 649, 661; physiological 645, 655, 704
ordinate 487
ortive amplitude 484–5

$\pi$ 420–1, 452–5, 573
pair: of amicable numbers 410; Descartes 410
pannus 911
parabola 360, 362, 421–8, 457–8, 486, 528, 537, 557; area of 426; rotation of 427; segment of 421, 427, 474
paraboloid 425, 427, 431; volume of 421, 425, 427, 431
parallax 497, 529, 533
parallel 560
parallelepiped 359, 491–2
parallelogramm 353, 421–2, 438
partition 390, 394
pathology 970–2
pedology 849
pentagon 439; area of 438; equilateral 459; non-regular 438; regular 438, 459, 524
perception: geometry of 661; notion of 679; psychology of 661; of shape 681; of space 724; visual 646, 717–18, 723, 725, 727
perimeter 577
permutation 377, 380; of factors 565
perspective 644–5, 684, 717, 724, 727, 1013, 1016, 1018, 1020, 1022
pharmacology xi, 251–2, 261, 263–4, 271, 818, 963, 968, 973–4
pharmacopoeia 970, 978
philosophy 248, 818, 914–15, 921, 975, 1009, 1011, 1018–19; natural 718
phonology 377
*phthisis*, tuberculosis of the lungs 916

physics 276, 643, 660, 662, 967, 1010, 1013–22; of light 673, 704; of perception 727; of transmission 724
physiognomy 1020
physiology 855, 966, 968, 970; of the eye 644–5, 717, 965
phytobiology 814, 839–41, 845
*piramis* (*rotunda*) 576
place (*locus*) 617; 'natural' 620
plague tracts 930, 953
planets: distances 24; order 84
planimetry 460
*pneuma* 675–6, 679, 682–3
point: of intersection of curves 363–4, 450; property of a fixed 375; rational 397
poison cups 954
politics 1014–15, 1019
polygon 420–1, 426, 454, 474; area of 421, 439, 441–2, 449–50, 452; regular 439, 441, 449–50, 452–3, 456–7, 484, 536, 538, 654; surface 432
polyhedron 456; area and volume of 440–4; non-regular 440; regular 440, 443–4, 452, 457; semi-regular 456–7
polynomial: equation 363–4; expressions 381; function 365, 393
polynomials 356–7, 359, 362, 388, 398; divisibility of 357; dominant 369; ring of 357
power 371, 400, 413; algebraic 357; of a point 363; of *n* successive integers (sum) 427; sixth 354; visual 679; from water and wind 780–4
precession 29–31, 296
primitive: Pythagorean triplets 403, 406; right-angled triangles 402–3, 405
prism, volume of 449
product 565
progressions 341–3, 345–6, 357, 395
projection 475–82; of astrolabe 480; azimuthal equidistant 194; central re-projection 672; conical 481; cylindric 481; doubly equidistant 194; of ecliptic 482; globular system 195; of light 687–9; of Marinus 192; orthogonal 476–7, 533, 536; perfect 481; stereographic 198–9, 476, 478–82, 493; *see also* cartography
proof 548
propagation: *see* light, rays
prophecy 1020
proportion 332, 561, 575; theory of 448, 461
proportionality of areas 426, 433
proto-geometric demonstration 352–3
psychology (brain, mental faculties) 966
Ptolemaic: astronomy (critical analysis) 25–34, 59–61, 74–83, 265; configuration 794
pulmonary circulation 951, 979–80
pyramid: area and volume of 439, 441, 443, 449, 452; regular pyramid 443, 654; truncated 449, 452
Pythagorean: proposition 448, 463; system (music) 584–613; theorem 433, 495, 520, 551; triangles 402–3; triplets 403, 406

*qanāt* (construction of) 753, 755–7
*qarasṭūn* 618, 637
*qibla* 128–9, 476–7, 479–80, 484, 500, 533; mathematical methods 141–7
*qiyās* 566
quadrangle 449, 451, 460, 466–7, 470; Lambert 466; Saccheri 468–9; spherical 483
quadrature 424, 448; of a circle 432; of lunules 418, 431–7; of parabola 427
quadrilateral 436, 483, 500–1, 503, 505–6, 509, 515, 533
quadrinomial 373
*quadriuium* 541, 551
quantitative: research 668; rules 665
quantities: geometric 450; primary 974; *see also* rule
quartic skew 397
*qubbat al-arḍ* 189
*qubbat arīn* 189

*rabāba* 581, 583, 604, 607, 610, 613
radiation 674, 681, 687, 719, 721, 724, 726; geometry of 720–1
radicals 349; resolution by 350, 352, 359–60, 363, 369
*radix* 577–9
rainbow 644, 656, 667
ratio 332; compound 501–2, 506; of sine to sine 520; theory 448, 461, 626, 639–40, 642
rational: Diophantine analysis 354, 357, 394–401, 414; numbers 355; parameter 396; positive numbers 350
ray 646–7, 679, 695, 722, 725; beam of 660; convergence 655, 660; direct 1013; discrete 651; fire 647; geometrical concept of 651; incident 648, 651, 663–5, 699, 720, 727; infinitely extensible 675; intromitted 727; luminous 660; perpendicular 695–7, 700; propagation of 646, 655, 682; rectilinear propagation of 649–51, 682; reflected 648, 651–4, 663–4, 720, 1013; refracted 659, 665; science of 646; solar 644, 647, 653–5, 659; tactile-visual 674–5; visual 644, 662, 677, 681–2, 687
reckoning (Indian) 540–4, 547–51, 561–2, 565–6, 577, 579, 1020; finger- 331–3, 338

rectangle 487
recurrence (rule of) 384, 406
reduction (of fraction) 545–6
reflection 655–6, 668, 675, 677, 703; law of 647, 663, 720, 728; of solar rays 644; of visual rays 644
refraction 655–9, 665–6, 668, 687, 687, 695, 699–701, 703, 725; angle of 675; index of 658; law of 665, 720, 724, 728; table of 393
regimen 913
*regula* 566
remainder 547
*res* 577–8
rhetorics 1025
rhombuses 438
root 350, 385, 541, 544, 546, 548, 562–3, 567–8, 577–8; cubic root 373–4, 382–4, 401; irrational 387, 388–9; negative 360, 363, 365, 366; positive 353, 360, 363, 365–8, 375, 381, 384; square root 382–4, 396, 398, 406
rotation of the earth 52
Ruffini-Horner (method of) 363, 367, 383–4, 387
rule of the four quantities 265, 504, 508, 533–5
ruler 454–5, 460

*saqiya* 771–4, 776
*scacherium* 550
scale: Babylonian sexagimal 336; of degrees 336; of sixty 331–7
secant 483, 493, 514, 557
second 545
series: convergent 530; of numbers 343–4, 387; of positive integers 384; of ratio 2 409
sexagesimal: fraction 336, 415, 544–7; number 451; scale 336, 340; system 331, 390
sextant of Rayy 10–11
*shabaka* 573
shadow 509, 514–15, 520, 523, 535; 649, 717; of an arc 512; of a gnomon 509–10, 513; of sun 510, 513; table of 513
*shadūf* 769
*shay'* 578
*shiyāf* (collyrium) 915
sign rule 354
sine 513–15, 521, 527; of the complement 514, 520; law of 484; table of 253, 496, 521–3, 527; theorem of 265, 503, 506–8, 516–18, 533
*sirsām* (meningitis) 917
smallpox 914–15, 923
solar theory: *Book on the solar year* 26–31; Ibn al-Shāṭir 88–90; Ptolemy 61–2
solar year 26–8
solid 419, 429, 431, 437–8, 440, 1017–18; angle 441, 443–4, 476; area of 431; problems 354, 359, 360; of revolution 429, 439, 451
sophistic 1018
soporifics (*mukhaddir*) 909, 943, 925, 945
space: affine 397, 400; atomist idea of 678; Euclidean 461; four-dimensional 492
speculum (vaginal) 948
sphere 438, 441–4, 457, 476, 648, 1018; area of 421, 451, 439, 559; burning 660–1; celestial 80–2, 266–9, 476, 479, 481, 484, 488–9, 657, 667, 1018; 'extreme' property of 439, 444; volume of 420–1, 429, 437, 439–40, 551
spirits (*pneumata*) 966
square 350, 353, 371, 376, 396, 399, 400, 457–9, 536, 561, 563, 567–8, 577–8; congruent 457; magic 414, 561, 866; of an integer 385; positive rational 395–6; sum of 343, 402, 404–6, 457; *see also* root
stars, altitudes 236–41; *see also* fixed stars
statics 614, 642; applied 632–42; geometrical 616, 619, 632; theorems of 614; theoretical 619–32
stereometry 448, 1025
stone (philosophical) 875, 882
stones (neck of bladder) 946
substances 868–9, 877–8
*substantia* 562, 577–8
substitution (algebraic technique) 356
subtraction 332, 335–7, 548–9
sum: of aliquot parts of an integer 409; of divisors of an integer 409–10; of the powers of natural integers 414; *see also* integral
summation 341–2, 346
sun, apparent size 47, 74; *see also* solar theory
sundials 163–8, 480, 489; gnomon of 480; shadow of 489
*ṣūrat al-arḍ* 796–81, 809
surgeons (*jarā'iḥīyūn*) 940
surgery 252, 920, 933, 942–5, 947–8, 950, 963
surgical instruments 906, 920, 946, 948–9
surveying: land 349, 454, 767; *see also* instruments 751, 766–9
synthesis 405–6, 502

table: Alfonsine 297–8; astronomical 391, 448, 1020; of chords 253, 391, 495, 511, 523–4, 532; of equations 510–11; Horner 384; of refractions 393; of shadow 513;

table: (*continued*)
of sines 253, 496, 521–3, 527; of tangents 510; timekeeping 173, 177–83; Toledan 287–91; trigonometric 253, 391; *zīj* 523
tablet ('dusty') 548, 572
talismans 880, 907, 938, 953; science of 1020
tangent 509–10, 514, 520, 527; function 500, 509–14, 532; rule 505, 508, 513–14, 534–5
*tanwīn* 950
Taylor expansion 368
technology: fine 785; mechanical 785, 794
teeth (extraction of) 946
temperaments 912, 967; theory of 972
tetrahedron 443–4
theodicy 1020
theology 1009, 1011, 1014–16, 1019
theorem: Archimedes-Hero 450; Chinese 408, 413; fundamental (of arithmetic) 410; of Geber265; hyperbolic and elliptic geometries 466; Ibn Qurra's 410; Menelaus 495, 497, 499–501, 503, 508, 510, 515–16, 518, 520, 532–3, 535; plane 503; planimetric 493; Pythagoras 433, 495, 520, 551; of sine 265, 503, 506–8, 516–18, 533; spherical 503; stereometric 493; Wilson 408, 413
*theoricæ planetarum* 291–3
theory: of algebraic equations 353, 356, 357, 361–2; of amicable numbers 409; of balance 632, 642, 855, 868; of bodies floating in liquid 632; of degrees 968, 974; of diffusion 794; *eidola* 673; of equations 354, 360; of floating of loaded ship 632; of gravitation 622; intromission 680; of inversive transformation 475; of linear and quadratic equations 353–2; of numbers 376, 379, 394, 401, 408–14, 854; 'object-copy' 673, 678, 680, 687; of parallel lines 460, 463–70, 493–4; of parity 408; of perfect number 409; of 'primary quantities' 974; of quadratic irrationalities 448; of radiation 720; of ratios (Eudoxus-Euclid) 448, 461, 626, 639–40, 642; of sensation 685; of ship 631; of simple machines 632; of tactile sensitivity 679; of tactile-visual ray 682–3; on the unity of the whole 857; of vision 644, 673, 678, 680, 717, 720–1, 723–5, 727–8; of visual emanation 721; of visual fire 725–6; of visual perspective 723–4; of visual *pneuma* 721, 724; visual ray 681; of the weightless lever 617; *see also* colour, lever, light, motion, solar
theurgy 1020
thing 567, 578; *see also* unknown
third 545
timekeeping: hydraulic 794; mathematical methods 173–6
times of the prayers 170–2
*tirfa* 217–20
tonsillectomies 946
tools (alchemy) 868, 876
torus 451
tracheotomy 945
transformation: affine 358, 363, 366, 368, 426–7, 471–3, 475, 494; equiaffine 473; projective 475–6, 481
translations, Hebrew 277–9
transmutation of metals 854, 857, 866, 868, 875, 879, 881
trees 814–16, 819, 820–38, 842, 846; forest 845, 847–8; fruit 819, 824–8, 838, 845–9; non-fruit 826–8, 838; shrubby 824
trepidation 296
triangle 460, 470, 509; acute 449; area of 434, 438, 449, 559, 573; arithmetic 378–80, 386, 414; equilateral 438, 451, 456; formulae of 497, 500–1, 535; height of 448; hypotenuse of 510; isosceles 433, 438–9; numerical right-angled 402–3, 405; obtuse 449; plane 495, 518; plane right-angled 499, 510; polar 496, 515–17, 519–20, 532; primitive right-angled 402–3, 405; Pythagorean 402–3; right-angled 449, 454, 495, 505–9, 516, 518–21, 533, 535; segment of 437; spherical 479, 483–6, 496, 506–7, 515, 518; spherical right-angled 497, 500, 515
triangulation (methods of) 769
trigonometric: functions 381, 433, 512; tables 253, 391, 362, 452
trigonometry 266, 376, 435, 437, 555; plane 433, 496, 520–1, 528, 769; spherical 258, 483–4, 528, 769, 496
trinomial 350, 353–4, 372–3, 399; *see also* equation
trisection of an angle 360, 420–1, 451, 455–7, 459, 523, 529–30, 557–8, 575
tuberculosis of the lungs 916
*ṭunbur* 581, 583, 587, 594, 604, 607–9, 612–13
typanum (drum) 769–71

*ʿūd* 581–3, 587, 592, 597–8, 601–7, 609–13, 796
unit 333–4, 362, 577
*unitas* 577
unknown (thing) 350–9, 362, 376, 378, 399
upper limit: concept of 421; properties of 423; uniqueness of 421, 423

upper planets and Venus: equant 6, 49, 77–8; Ibn al-Shāṭir 108–11; al-Juzjānī 103–4; latitude 68–70; Ptolemy 64–5; al-Ṭūsī 114–15; al-ʿUrḍī 104–8

variables, change of 356, 400
vegetables 814, 816, 820, 829–38, 844–5, 848–9
Venus: arc of visibility 44–5; latitude 72–3; *see also* upper planets
vessels, trick 786
vine (yards) 815, 824, 826, 838–9, 842, 844–5, 847, 849
visibility 499
visible object 646–7, 662, 721
Visigothic (script) 542
vision 666: anatomy of 724; double (diplopia) 702–3; geometry of 646; physiology of 646, 724; role of air and luminosity 647; theory of 649, 651, 660–3
volume 333; of prism, pyramid, cylinder, cone, sphere 449

*waqf* 905, 935, 939
water: -clocks 785, 788–92; lifting (science of) 618; properties 637; -raising machines 769–79, 783, 789; -supply 752–64, 769, 774; weight of 638–9; -wheel (horizontal 782; overshot 781; undershot 780)
weighing 392, 617; science of 614, 626
weight 619; of metals and minerals 618–19; of the beam 616; of water 638–9; science of 618, 632, 1013, 106, 1020; specific 638–42
wind-rose 207
wounds 947

*ysosceles* 574

*zams* 216–17
zeros 334, 340; rule of 383, 546–7
*zīj* 1, 391, 448, 486, 497, 501, 508–15, 523, 529, 808

# 3. Index of treatises

Book titles are given in English, Latin or Arabic, according to how they are quoted in the text.


Abraham b. Ezra
*Liber de rationibus tabularum* 253
Abraham bar Ḥiyya
*Liber embadorum* 492, 563
Abū Kāmil
*Kitāb fī al-jabr wa-l-muqābala* 394–5, 397, 563–8
Abū al-Khayr
*Kitāb al-filāḥa* 846
Abū Maʿshar
*De magnis coniunctionibus* 285, 304
*Introductorium maius* 285
*Kitāb al-ulūf* 249
al-Afḍal al-ʿAbbās b. ʿAlī
*Kitāb bughyat al-fallāḥīn* 846
Agathodaimon (attributed to)
*Risālat al-ḥadhar* 860
Albert of Saxony
*Tractatus proportionum* 555
Alexander of Villa Dei
*Carmen de algorismo* 547–8
Alfonso
*Meyashshēr ʿāqōb* 455, 493
Amico, Giovanni Battista
*De motibus corporum caelestium* 303
Anonymous or collective
*Account of China and India* 798, 810
*Agrimensores* 551, 554, 556, 573
*Algorismus Ratisbonensis* 570
*Anwāʾ* (*Treatises on the*) 2, 3
*Arithmetic of Bamberg* 549
*Arithmetic of Treviso* 549
*Calendar of Córdoba* 246, 250–1, 257
*Codex Narcianus* 861
*Commentary on Liber de ponderibus* 557
*De canonio* 616–17, 626–7
*De duabus lineis* 560
*De inquisicione capacitatis figurarum* 557
*De triangulis* 558–9, 576
*Dhikr bilād al-Andalus* 245
*Filāḥā hindiyya* 261
*Geoponika* 261
*Helcep Sarracenicum* 540
*Historiam adversos paganos libri septem* 246
*Ilkhanide tables* 1003–4
*al-Istidrāk ʿalā Baṭlamyūs* 58, 74, 83–4
*Kitāb al-buldān* 799
*Kitāb fī sanat al-shams* 25–31, 34, 47, 289
*Kitāb al-hayʾa* 83, 126
*Liber d'abaco* 569
*Liber mercurii triplicis de VI rerum principiis* 890
*Liber sacerdotum* 888, 893
*Libro de las Cruzes* 245, 257
*Libros del Saber* 169
*Mappae Clavicula* 888–9
*Morienus* 889–90
*Muṣḥaf al-ḥayāt* 860
*Patiganita* 346
*Persian Tables* 281
*Quadriuium* 551, 560
*Risāla fī al-ṭibb wa-l-filāḥa* 817
*Risālat Mariya bint Sāba al-malik al-qibṭī ilā Aras* 861
*Risālat al-tāj wa khilqāt al-mawlūd* 861
*Speculi Almukefi compositio* 560
*Sulbasūtras* 457
*Tabula Smaragdina* 249
*Theorica planetarum Gerardi* 292
*Toledan Tables* 250, 258, 259
*ʿUmdat al-ṭabīb fī maʿrifat al-nabāt li-kull labīb* 262
*al-Zīj al-mumtaḥan* 25–6, 34, 47, 50, 56, 993
*Zīj al-Shāh* 8
*Zīj al-Sindhind* 250, 254, 258
for other anonymous or collective works, *see also* 892–4
al-Anṣārī, Abū Zayd
*Kitāb al-nabāt wa-l-shajar* 814
Anthemius of Tralles
*On Burning Mirrors* 656

Apollonius of Perga
*Conics* 448, 473, 476, 478, 486
*Plane Loci* 472
Apollonius of Tyana
*Kitāb al-aṣnām al-sab'a* 859
*Kitāb al-qamar al-akbar* 859
*Sirr al-Khalīqa (Kitāb al-'ilal)* 858–9, 861, 890
Archelaos (attributed to)
*Risālat madd al-baḥr dhāt al-ru'ya* 855
*Turba philosophorum* 854–5, 860–2, 869–70, 893, 900
Archimedes
*Equilibrium of Planes* 616
*Fī al-thiql wa-l-khiffa* 616, 630
*Lemmas* (*Liber assumptorum*) 451, 455, 490, 557
*On Conoids and Spheroids* 419, 472, 486
*On the Floating Bodies* 616, 630–1
*On the Measurement of the Circle* 341, 441, 449–50, 453, 557
*On the Method* 419
*On Parallel Lines* 464
*On the Quadrature of the Parabola* 419, 486
*On Spirals* 419, 486, 557
*The Sphere and the Cylinder* 354, 371–2, 419, 421, 451, 557
Aristarchus of Samos
*On the Sizes and Distances of the Sun and the Moon* 7, 19, 57
Aristotle
*Categories* 1012, 1020
*De anima* 704, 706, 718, 1020
*De animalibus* 729, 975–6, 1014
*De generatione et corruptione* 967, 1014, 1020
*De sensu* 706, 718, 1020
*Economics* 1019
*Ethics* 1019
*Historia animalium* 1020
*Isagoge* 1020–1
*Mechanica* 614
*Metaphysics* 85, 266, 968, 1015, 1022
*Meteorologica* 644, 706, 718, 855, 876, 895, 1014, 1020
*On the Heavens* 1014, 1020
*On Metals* 1014
*On Plants* 817–8, 1014, 1020–1
*On the World* 1021
*Parva naturalia* 718
*Peri-Hermeneias* (*On Interpretation*) 1012, 1020
*Physics* 294, 431–2, 620, 973, 1014, 1020
*Poetics* 1012, 1020, 1024
*Politics* 1015
*Posterior Analytics* 1012, 1017, 1020
*Prior Analytics* 1012
*Rhetorics* 1012, 1020, 1024
*Sophistics* 1012, 1020
*Topics* 968, 1012, 1020
Arnald of Villanova
*Aphorismi de gradibus* 974
*De consideratione operis medicine* 974
*De intentione medicorum* 974
*De parte operativa* 966
*Experimenta* 978
Artephius
*De perfecto magisterio* 893
*Miftāḥ al-ḥikma* 860
Āryabhaṭa
*Āryabhaṭīya* 8
al-Aṣma'ī
*Kitāb al-nabāt wa-l-shajar* 814, 850
Augustine of Hippo
*De genesi ad litteram* 725
Autolycus
*On the Moving Sphere* 7, 18
*On Risings and Settings* 7, 19
Avenzoar
*Theisir* 978

Bacon, Roger
*Communia Mathematica* 576
*De erroribus medicorum* 973
*Opus tertium* 295
al-Baghdādī, 'Abd al-Laṭīf
*Kitāb al-i'tibar* 850
al-Baghdādī, Ibn Ṭāhir
*al-Takmila* 331, 342, 344, 346–7, 383
al-Bakrī
*Kitāb al-masālik wa al-mamālik* 805
Banū Mūsā
*Kitāb al-ḥiyal* 618, 786
*On the Measurement of Plane and Spherical Figures* 383, 420, 450, 557, 559
*al-Shakl al-mudawwar al-mustaṭīl* 458
Bartholomeu
*De proprietate rerum* 971
al-Battānī
*Almanach* 259
*al-Zīj al-Ṣābī* 18, 46
Bede
*De temporum ratione* 284
Benvenutus Grapheus of Salerno
*De oculis* 965
al-Bīrūnī
*Fī anna lawāzim tajzī' al-maqādīr ilā lā nihāya . . .* 468
*Fī ifrād al-maqāl fī amr al-aẓlāl* 478, 489, 513
*Fī ikhrāj mā fī quwwat al-asṭurlāb ilā al-fi'l* 478–9
*Fī al-nisab* 619, 638
*Fī tasṭīḥ al-ṣuwar wa tabṭīḥ al-kuwar* 480

al-Bīrūnī (*continued*)
*Istīʿāb al-wujūh al-mumkina fī ṣanʿat al-asṭurlāb* 481
*Keys of Astronomy* 503–8, 513, 515–16, 519
*On Chords* 523
*al-Qānūn al-Masʿūdī* 18–19, 52–3, 57, 392, 454, 477, 494, 523, 527–30, 537
*Taḥdīd nihāyāt al-amākin* 187, 190, 476
al-Biṭrūjī
*De motibus celorum* 294
*Kitāb fī al-hay'a* 85, 267–8, 279, 305
Bolos of Mendes
*Georgika* 816
Bradwardine, Thomas
*Geometria speculativa* 446
*Tractatus de Proportionibus* 555
Brâhmagupta
*Khaṇḍakhādyaka* 8, 391, 499, 528
*Mahassidhanta* 8
al-Būzjānī, Abū al-Wafā'
*Fī mā yaḥtāju al-ṣāniʿ min al-aʿmāl al-handasiyya* 449–50, 456
*al-Manāzil al-Sabʿ* 348

Calandri, Pier Maria
*Tractato d'abbacho* 570
Campanus of Novara
*Commentary of Euclid* 555
*Theorica planetarum* 292–3
Capella, Martianus
*De nuptiis philologiae et Mercuri* 268, 551
Cardano
*Ars Magna* 565, 569
*De subtilitate* 446
*Practica arithmeticae* 570
Cassius Felix
*De medicina* 964
Chuquet
*Triparty* 569–70
Columella
*De re rustica* 247, 846–7
Constantine the African
*De gradibus* 968, 981
*De oculis* 966, 981
*Isagoge* 966–70, 981
*Pantegni* 964–71, 977, 981
*Viaticum* 966, 970–1, 981
Copernicus
*Commentariolus* 111, 122, 299, 302–3, 305
*De revolutionibus* 103, 108, 111, 122, 297, 299, 303

Dagomari
*Trattato d'aritmetica* 569
Dhū al-Nūn al-Miṣrī
*Kitāb al-rukn al-akbar* 864
*Kitāb al-thiqa fī al-ṣināʿa* 864
al-Dīnawarī
*Kitāb al-nabāt* 814–15, 817, 821–39
Diodorus
*Analemma* 476, 478
Diophantus
*Arithmetica* 349, 356, 397, 399, 401–2, 404, 564, 569
*The Art of Algebra* 356, 397
Dioscorides
*De materia medica* 251, 813, 817

Emmanuel Bonfils of Tarascon
*The Six Wings* 281
Euclid
*Catoptrica* 7, 18
*Conics* 486
*Data* 7, 18, 372
*Elements* 4, 35, 106, 258, 277, 341, 349, 351, 353–5, 357, 402–3, 408–9, 412, 418–20, 447–9, 452, 455, 460–4, 469, 471, 490, 493–4, 518, 536, 551–6, 568, 573, 575, 616, 1003, 1019
*Optics* 7, 18, 644–7, 649, 652, 656, 669
*Phenomena* 7, 18
Eutocius
Commentary on *The sphere and the cylinder* of Archimedes 555

al-Fārābī
*al-Ḥiyal al-rūḥāniyya* 456
*Iḥṣā' al-ʿulūm* 644, 1011–15
*Kitāb al-mūsīqī al-kabīr* 594, 601–5
*al-Madkhal ilā al-handasa al-wahmiyya* 492
*Sharḥ al-mustaghlaq min muṣādara min al-maqāla al-ūlā wa-l-khāmisa min Uqlīdis* 471
al-Farghānī
*Kitāb fī jawāmiʿ ʿilm al-nujūm* 24, 292
*Kitāb ṣanʿat al-asṭurlāb* 478
al-Fārisī
*Tanqīḥ al-manāẓir* 668, 671, 703
al-Fazārī and Yaʿqūb b. Ṭāriq
*Zīj al-Sindhind al-kabīr* 20
Fibonacci
*Liber abaci* 407, 493, 547, 549, 563–9
*Liber quadratorum* 407
*Practica Geometriae* 493, 556, 559

Galen
*De complexionibus* 967
*De ingenio sanitatis* 971
*De interioribus* 971
*De locis affectis* 971
*De malicia complexionis* 974
*De morbo et accidenti* 971, 974

*De simplici medicina* 968
*De usu partium* 709, 711, 714, 951, 970
*Techné* 964
*Tegni* 970
Garlandus, Johannes
*Book of Alums and Salts* 873
al-Gharnāṭī, Abū Ḥāmid
*al-Muʿrib ʿan baʿḍ ʿajāʾib al-Maghrib* 263
Gerard of Brussels
*Liber de motu* 556
Gerbert
*Quatratum geometricum* 556
al-Ghāfiqī
*Book of Simples* 819
Ghaligai
*Summa* 570
al-Ghazālī
*Revivification of the Sciences of the Faith* 1008
Grosseteste
*De iride* 719
*De lineis, angulis, et figuris* 719

Ḥabash al-Ḥāsib
*al-Zīj al-dimashqī* 32, 511, 529
al-Ḥabīb
*Kitāb al-Ḥabīb* 860–1
al-Harawī
*Kitāb al-ziyārāt* 810
al-Hāshimī
*Kitāb fī ʿilal al-zījāt* 19, 253
Heraclius
*Kitāb Hirakl al-akbar* 862
Hermes
*al-Falakiyya al-kubra* 858
*Kitāb Hirmis ilā Tāt fī al-ṣanʿa* 858
*Risālat Qabas al-qābis fī tadbīr Hirmis al-Harāmisa* 858
*Ṣaḥīfat Hirmis al-ʿuẓma* 858
*Risālat al-sirr* 858
Hero of Alexandria
*Mechanics* 617–18, 633
*Metrica* 448
Hippocrates
*Aphorisms* 246, 977
*Epidemics* 916, 938
Hippolytus
*Refutation of All the Heresies* 870
Hugues de Saint Victor
*Practica geometriae* 554, 556
Ḥunayn b. Isḥāq
*Book of the Questions on the Eye* 683
*Isagoge Iohannitii* 963–4, 970, 981
*Kitāb al-ʿashr maqālāt fī al-ʿayn* 682–3, 911, 940, 948
*al-Masāʾil fī al-ṭibb li-l-mutaʿallimīn* 911, 932, 941–2
*Tarkīb al-ʿayn* (*De oculis*) 717, 965
Hypsicles
*On the Ascensions of Stars* 7, 19

Ibn Abī al-Bayān al-Isrāʾīlī
*al-Dustūr al-bīmāristānī* 931
Ibn ʿAlī al-Ruhāwī, Isḥāq
*Adad al-ṭabīb* 938
Ibn Arfaʿ Raʾs
*Kitāb ghāyat al-surūr fī sharḥ al-ṣudūr* 874
*Shudhūr al-dhahab* 873
Ibn ʿĀṣim (al-Gharbāl)
*Kitāb al-anwāʾ wa-l-azmina* 257, 274
Ibn al-ʿAwwām al-Ishbīlī
*Kitāb al-filāḥa* 848
Ibn Bājja
*Kitāb al-nabāt* 818
*Kitāb al-tajribatayn* 818
Ibn al-Baṣṣāl
*Kitāb al-qaṣd wa-l-bayān* 257, 848
Ibn Baṭṭūṭa
*Riḥla* 819
Ibn al-Bayṭār
*Jāmiʿ li-mufradāt al-adwiya wa-l-aghdhiya* 271, 816, 819, 821–39
Ibn Buṭlān
*Daʿwat al-aṭibbāʾ* 927
*Taqwīm al-ṣiḥḥa* 927
Ibn Faḍl Allāh al-ʿUmarī
*Masālik al-abṣār* 807
Ibn Ghāzī al-Miknāsī
*Bughyat al-ṭullāb fī sharḥ minyat al-ḥussāb* 348
Ibn Hāʾim (of Seville)
*Zīj al-kāmil fī al-taʿālim* 265
Ibn Ḥajjāj al-Ishbīlī
*Kitāb al-mughnī fī al-filāḥa* 846
Ibn al-Haytham
*Discourse on Light* 661, 665
*Fī birkār al-dawāʾir al-ʿiẓām* 484
*Fī ḥall shukūk kitāb Uqlīdis fī al-Uṣūl* 462, 466, 468
*Fī istikhrāj samt al-qibla* 477
*Fī al-musabbaʿ fī al-dāʾira* 459
*Liber de speculis comburentibus* 560, 718–19
*On Analysis and Synthesis* 437
*On the Burning Sphere* 661, 665–8, 669
*On the Configuration of the World* (attributed to) 295, 298
*On the Figures of Lunules* 435–7, 444–5
*On the Formation of Shadows* 661
*On the Halo and the Rainbow* 661, 667
*On Isoperimetrics* 440
*On the Light of the Moon* 661
*On the Light of Stars* 661
*On the Lunules* 432, 445

Ibn al-Haytham (*continued*)
*On Parabolical Burning Mirrors* 661
*On the Quadrature of the Circle* 432–3
*On the Shape of the Eclipse* 661
*Optics* (*Kitāb al-Manāẓir*) 470, 493, 558–60, 661–71, 686, 688, 701, 707, 710–15, 718–20, 726
*Sharḥ muṣādarāt kitāb Uqlīdis fī al-Uṣūl* 462–3, 466, 468
*al-Shukūk ʿalā Baṭlamyūs* 17, 19, 58, 74–82, 126
*Spherical Burning Mirrors* 661, 664
Ibn Ḥazm
*Marātib al-ʿulūm* 1008
Ibn Hūd
*al-Istikmāl* 258
Ibn al-ʿIbrī
*Chronography* 465
Ibn ʿIrāq, Abū Naṣr
*Azimuths* 506
*On Spherical Triangles* 506–7, 516
Ibn Juljul
*Ṭabaqāt al-aṭibba'* 246, 249
Ibn Khalaf al-Murādī
*Kitāb al-asrār fī natā'ij al-afkār* 261
Ibn Khaldūn
*Muqaddima* 766, 879, 907, 929, 957–8, 1023
Ibn al-Khaṭīb
*Iḥāṭa* 271
Ibn Khurdādhbih
*Kitāb al-masālik wa-l-mamālik* 797
Ibn al-Mājid
*Ḍarība al-ḍarā'ib* 216–17
*Ḥawiya* 217
*Sufaliyya* 211
Ibn Mammātī
*Qawānīn al-dawāwīn* 849
Ibn Māsawayh
*Daghal al-ʿayn* 669
*Nawādir al-ṭibb* 977, 982
Ibn Muʿādh
*De crepusculis* 279, 718
*Kitāb majhūlāt qisī al-kura* 258, 519–20
*Maqāla fī sharḥ al-nisba* 258
*Tabulae Jahen* 258
Ibn al-Nafīs
*Perfected Book on Ophthalmology* 933
*Sharḥ al-Qānūn* 932
Ibn al-Quff
*Kitāb al-ʿumda fī ṣināʿat al-jirāda* 933
Ibn Qutayba
*Kitāb al-anwā'* 257
*Kitāb ʿUyūn al-Akhbār* 849
Ibn al-Raqqām
*Risāla fī ʿilm al-ẓilal* 273
Ibn Riḍwān, ʿAlī
*Kitāb dafʿ maḍārr al-abdān bi-arḍ Miṣr* 927
Ibn Rushd
*Commentary on Aristotle's De anima* 718
*Commentary on Aristotle's Metaphysics* 266
*Epitome of Aristotle's Parva Naturalia* 718, 723
*Kitāb al-kulliyāt* (Colliget) 264, 975–7, 983
*Liber canonis* 718
*The Epitome of the Almagest* 280
Ibn Rusteh
*al-Aʿlāq al-nafīsa* 798
Ibn Sahl
*On Burning Instruments* 657–60, 667
*Celestial sphere* 657, 665, 667
Ibn Samjūn
*Jāmiʿ al-adwiya al-mufrada* 818
Ibn al-Shāṭir
*Nihāyat al-sūl* 103, 108, 126–7, 257, 302
Ibn Sīda
*al-Muḥkam* 816
*al-Mukhaṣṣaṣ* 814, 816
Ibn al-Sikkit
*Kitāb al-nabāt wa-l-shajar* 814
Ibn Sīnā
*Avicennae de congelatione et conglutinatione lapidum* 875–6
*De anima* 718, 876, 966
*De mineris* 895
*De viribus cordis* 974, 983
*Fī al-ālāt al-raṣadiyya* 12
*Fī aqsām al-ʿulūm al-aqliyya* 1019, 1025
*Kitāb al-maʿādin wa-l-āthār* 877
*Kitāb al-najāt* 684
*Miʿyār al-aql* 618
*al-Qānūn fī al-ṭibb* 270, 277, 685, 875, 921–6, 950–1, 966, 970–7, 979, 983, 998
*al-Shifā'* 25, 606, 684, 818, 850, 875–6, 879, 1017, 1021–2; *al-Burhān* 1017
*Urjūza fī al-ṭibb* 975
(attributed to) 875–7
Ibn Turk
*Algebra* 562
Ibn Umayl
*Kitāb al-mā' al-waraqī wa-l-arḍ al-najmiyya* 870–1, 874
*Risālat al-shams ...* 870, 972
Ibn Wāfid
*Abenguefith de medicamentis simplicibus* 818, 983
Ibn Waḥshiyya
*Filāḥā nabaṭiyya* 261, 813–14, 817, 819, 821–50
Ibn al-Wardī
*Kharīdat al-ʿajā' ib* 850

Ibn Yaḥyā, al-Waṭwāṭ al-Kutubī,
  *Kitāb mabāhij al-fikar* 846
Ibn Yūnus
  *al-Zīj al-ḥākimī al-kabīr* 19, 51, 501, 513, 524, 994
Ibn Yūsuf, Aḥmad
  *De proportione et proportionalitate* 555–6
Ibn al-Zayyāt al-Tādilī (attributed to)
  *Kitāb al-madd wa-l-jazr* 268
Ibrāhīm b. Sinān
  *Fī al-asṭurlāb* 478
  *Fī misāḥat al-qaṭ' al-mukāfi'* 474
  *Fī rasm al-quṭū' al-thalātha* 458, 473, 475
al-Idrīsī
  *Treatise of simples* 819
Ikhwān al-Ṣafā'
  *Rasā'il* 249, 850, 872
al-'Irāqī, Abū al-Qāsim
  *Kitāb al-'ilm al-muktasab fī zirā'at al-dhahab* 874
Isaac Israelo of Toledo
  *Yesod Olam* 279
al-Iṣfahānī
  *Kitāb al-aghānī* 598
Isidore of Seville
  *De natura rerum* 245–6
  *Etymologies* 245–6

Jābir b. Aflaḥ
  *Iṣlāḥ al-Majisṭī* 84, 265–6, 280, 446, 509
Jābir b. Ḥayyān
  *Kitāb al-raḥma* 865
  *Kitāb al-zahra* 865
  *The Books of Balances* 865
  *The Hundred and Twelve Books* 865
  *The Seventy Books* 865, 891
  *The Ten Books of Adjustment* 865
  *Ustuquss al-uss* 861–2
al-Jaghmīnī, Maḥmūd
  *al-Mulakhkhaṣ fī al-hay'a* 480
Jaldakī
  *al-Burhān* 859
  *Kashf al-asrār* 874
  *Kitāb al-anwār al-durār fī iḍāḥ al-ḥajar* 874
  *Kitāb lawāmi' al-afkār al-muḍī'a* 874
  *Kitāb al-shams al-akbar* 861
  *Nihāyat al-ṭalab fī sharḥ al-muktasab* 874
Jawād
  *Monk's Medicine* 247
al-Jawharī
  *Iṣlāḥ li-Kitāb al-Uṣūl* 464
al-Jazarī
  *Kitāb fī ma'rifat al-ḥiyal al-handasiyya* 618
Johannes of Tinemue
  *Liber de curuis superficiebus* 557
John of Murs
  *Expositio tabularum Alfonsi regis Castello* 297
  *Quadripartitum numerorum* 568
John of Sacrabosco
  *Algorimus Vulgaris* 547–8
John of Saint-Amand
  *Antidotarium Nicolai* 973
  *Revocativum memorie* 973
John of Toledo
  *Liber Algorismi (alchorismi)* 549, 561–2, 565
John of Tournemire
  *Clarificatorium super Nono Almansoris* 972
al-Jūzjānī
  *Tarkīb al-Aflāk* 58
al-Juzūlī
  *Maṭāli' al-budūr* 850

al-Karajī
  *al-Badī'* 356, 398–401
  *al-Fakhrī* 356, 397–9, 568
  *al-Kāfī fī al-ḥisāb* 332, 348, 450
al-Kāshī
  *Miftāḥ al-ḥisāb* 341, 387, 450, 452, 521
  *al-Risāla al-muḥīṭiyya* 453, 531
  *Zīj-i Khāqānī* 393, 509, 532
Kautyla
  *Book of Poisons* 870
Kepler
  *Astronomia pars Optica* 493
  *Epitome astronomiae Copernicanae* 284
Khālid b. Yazīd
  *Firdaws al-ḥikma* 864
  *Kitāb al-kharazāt* 864
  *Kitāb al-ṣaḥīfa al-kabīr* 864
  *Kitab al-ṣaḥīfa al-ṣaghīr* 864
  *Kitāb Waṣiyyatihi ilā bnihi fī al-ṣan'a* 864
  *Liber trium verborum* 893
al-Kharaqī, 'Abd al-Jabbār
  *Muntahā al-idrāk fī taqāsīm al-aflāk* 479
al-Khayyām
  *Kitāb al-ḥikam* 639
  *On the division of a quarter of a circle* 362
  *Sharḥ mā ashkāla min muṣādarāt kitāb Uqlīdis* 463, 467
al-Khāzin
  *Commentary on the Almagest* 49
  *Kitāb fī sirr al-'ālamīn* 49
  *Zīj al-ṣafā'iḥ* 256, 515
al-Khāzinī
  *Kitāb mīzān al-ḥikma* 618–41
al-Khwārizmī, Abū 'Abd Allāh
  *Mafātīḥ al-'ulūm* 618, 632, 1008
al-Khwārizmī
  *Dixit Algorizmi (De Numero Indorum)* 540–7, 571–2

al-Khwārizmī (*continued*)
*Fī ʿamal siʿa ayy mashriq shiʿta min al-burūj fī ayy ʿarḍ shiʿta bi-l-handasa* 484–5
*al-Jabr wa-l-muqābala* 370, 561–3, 566
*al-Jamʿ wa-l-tafrīq* 331
*Liber Alchorismi* 540–8, 571–2
*Liber pulueris* 540–7, 571–2
*Liber Ysagogarum Alchoarismi* 540–8, 551–3, 571–4
*Maʿrifa samt min qabl irtifāʿ* 485
*On Arithmetic* 382
*On Hindu arithmetic* 331
*Ṣūrat al-arḍ* 489
*Zīj al-Sindhind* 21
al-Kilābī, Abū Zayd
*Kitāb al-nawādir* 814
al-Kindī
*De aspectibus* 645, 649, 1011, 1024
*De gradibus* 973
*De medecinarum compositarum gradibus* 252
*Epistle on the Number of the Books of Aristotle* 1009–11, 1020–2
*Faḍā'il Miṣr* 854
*Fī ʿamal al-samt ʿalā al-kura* 483
*Fī ʿamal shakl al-muwassiṭayn* 457
*Fī al-marāyā al-muḥriqa* 656
*Fī al-ṣināʿat al-ʿuẓmā* 23, 438, 446
*First Philosophy* 1011, 1024
*On bodies which are immersed in water* 630, 655
*On Quiddity of Science* 1009, 1023
*Taqsīm al-muthallath wa-l-murabbaʿ* 457
*The sphere is the largest of the solid figures...* 438
for other works, *see also* 1009
Kūshyār b. Labbān
*Fī uṣūl al-ḥisāb al-hindī* 548; *Arithmetic* 383

Leonardo of Cremona
*Artis metrice practice* 559
Levi b. Gerson
*Astronomy* 280
*The Wars of the Lord* 279

al-Maghribī, Muḥyī al-Dīn
*Tasṭīḥ al-asṭurlāb* 482
al-Māhānī
*Fī maʿrifa al-samt li-ayy sāʿa fī ayy mawḍiʿ aradta* 485
Maimonides
*The Guide for the Perplexed* 278
*Kitāb al-fuṣul (Aphorisms)* 931
*Sanctification of the New Moon* 266
*Sharḥ asmā' al-ʿuqqār* 264, 819
al-Majrīṭī
*Ghāyat al-ḥakīm (Picatrix)* 249, 872–3, 880
*Rutbat al-ḥakīm* 260, 872, 880
al-Majūsī
*Kitāb Kāmil al-ṣināʿa al-ṭibbiyya* 964, 967, 982
al-Marrākushī
*Jāmiʿ al-mabādi' wa-l-ghāyāt fī ʿilm al-mīqāt* 161, 177, 459
Māshā'allāh
*Book of Eclipses* 282
al-Masʿūdī
*Kitāb al-Tanbīh* 55, 193
*Murūj al-Dhahab* 193, 798
Menelaus
*Sphaerica* 7, 19, 448, 483, 497, 502, 518, 520

al-Nābulsī, ʿAbd al-Ghanī
*Kitāb ʿalam al-malāḥa* 846
Nemesius of Emesa
*De natura hominis* 965–6
Nemorarius
*Arithmetic* 556, 575
*De numeris datis* 563–5
*Liber philotegni* 558
Nicomachus of Gerasa
*Introduction to Arithmetic* 341, 408
al-Nuwayrī
*Nihāyat al-arab* 807, 850

Oribasius
*Synopsis* 964
Ostanes
*Kitāb al-fuṣūl al-ithnay ʿashar fī ʿilm al-ḥajar al-mukarram* 862
*Muṣḥaf al-ḥakīm* 862

Pacioli
*Summa* 559, 569
Pecham
*Perspectiva communis* 721
Peurbach
*Theoricae novae planetarum* 298
Peurbach/Regiomontanus
*Epitome in almagestum Ptolemaei* 298, 300
Piero della Francesca
*Trattato d'abaco* 570
Pietro d'Abano
*Conciliator* 976–7
Platearius
*Circa instans* 968, 970
Plato
*Kitāb al-Rawābīʿ* 855
*Laws* 1019
*Politics* 1019
*Republic* 1016, 1021, 1023
*Timaeus* 705, 717, 725, 965

Pseudo-Aristotle
*Mechanical Problems* 614–15, 617–18, 620, 622, 626, 628, 633, 642
Pseudo-Campanus
*Tractatus de proportione et proportionalitate* 555
Pseudo-Democritus
*Physika kai Mystika* 855–6
Pseudo-Euclid
*Catoptrics* 644–5, 649, 669, 718–19
*Liber Euclidis de ponderoso* 616–17, 621, 631
*The Book of Euclid on the Balance* 616, 626, 628
Pseudo-Khālid
*Firdaws al-ḥikma* 862
Pseudo-Nemorarius
*Liber de proportionibus* 555
*Liber de triangulis* 555–6, 564
Pseudo-Ṭūsī
*Exposition of Euclid* 462, 469–70, 493
Ptolemy
*Almagest* 4, 6–9, 16–19, 21–4, 28–32, 34, 37, 47, 50–1, 54–6, 59–62, 67, 69–70, 74–5, 77–82, 84, 104, 110, 126, 141, 253–5, 265–7, 277–8, 287, 289, 292, 438, 448, 483, 489, 495, 497, 499, 500–2, 505–6, 508, 518, 524–5, 529, 532–3, 536, 554, 993, 1003
*Analemma* 160
*Geography* 141, 188, 193, 199, 254, 489
*Handy Tables* 4, 7, 21, 141, 253, 289–90, 499
*Optics* 17, 74–5, 644, 655, 657, 669, 718–20, 728
*Phaseis* 3, 4, 7, 18, 23, 44, 45
*Planetary Hypotheses* 4, 6, 7, 17, 18, 22, 24, 44, 49, 59, 65, 74, 80–2, 274, 280, 293, 295, 298
*Planisphaerium* 254–5, 285, 476, 478, 872
Pythagoras
*Kitāb al-muṣaḥḥaḥāt* 854

al-Qalaṣādī
*Riḥla* 272
al-Qalqashandī
*Ṣubḥ al-aʿshā* 807
al-Qazwīnī
*ʿAjā'ib al-makhlūqāt* 850
al-Qūhī
*Fī ʿamal ḍilʿ al-musabbaʿ al-mutasāwī al-aḍlāʿ* 459
*Fī ʿamal mukhammas mutasāwī al-aḍlāʿ* 459
*Fī al-birkār al-tāmm* 459
*Mas'alatān handasiyyatān* 475
Qusṭā b. Lūqā
*Hay'at al-aflāk* 55
*Kitāb ʿilal mā yaʿriḍu fī al-marāyā al-muḥriqa...* 669–70
Qusṭūs
*Filāḥa rūmiyya* (*Georgika*) 261, 816

al-Rāzī
*Kalām al-furūq bayna al-amrāḍ* 941
*Kitāb fī al-jadarī wa-l-ḥaṣba* 914–15
*Kitāb al-Manṣūrī* 683, 718, 867, 915, 937–8, 970, 972
*Kitāb fī al-shukūk ʿalā Jālīnūs* 74, 683, 975
*Sirr al-asrār* (*Secretum secretorum*) 867–9, 893
*Sirr ṣināʿat al-ṭibb* 978
for other works, *see also* 982
Regiomontanus
*De triangulis* 266, 509
Richard of Wallingford
*Quadripartitum* 555
Rudolff, Christoff
*Algebra* (*Coss*) 492, 570

Saccheri
*Euclides ab omni naevo vindicatus* 469
Ṣadr al-Sharīʿa
*Kitāb al-Taʿdīl* 122, 127
Ṣafī al-Dīn
*Kitāb al-adwār* 609
*al-Risāla al-Sharafiyya* 609
Ṣāʿid al-Andalusī
*Ṭabaqāt al-Umam* 254, 257, 259
al-Sālār, Ḥusām al-Dīn
*Muqqaddimāt li tabyīn al-muṣādara allatī dhakarahā Uqlīdis fī ṣadr al-maqāla al-ūlā fī mā yataʿallaqu bi-al-khuṭūṭ al-mutawāziya* 468
al-Samaw'al
*al-Bāhir* 356, 401
*al-Qiwāmī fī al-Ḥisāb al-Hindī* 383, 388, 390
al-Shīrāzī
*Durrat al-tāj li-ghurra al-dībāj* 462
*Nihāyat al-idrāk* 96–7
*Tūḥfa* 99, 118
al-Sijzī
*Fī misāḥat al-ukar bi-l-ukar* 491
*On the asymptote to an equilateral hyperbola* 418
Simon of Castello
*De proportionibus uelocitatum in motibus* 555
Simon of Genoa
*Synonyma/Clavis sanationis* 979
Sinān b. Thābit b. Qurra
*Kitāb al-anwā'* 18, 23

Sisebut
*Epistula metrica ad Isidorum de libro rotarum* 245
al-Ṣūfī
*Kitāb ṣuwar al-kawākib al-thābita* 19, 50

al-Ṭabarī, ʿUmar b. Farrukhān
*Liber Universus* 249
Taqī al-Dīn b. Maʿrūf
*Arithmetics* 380
Thābit b. Qurra
*Area of a segment of a parabola* 421–5
*Fī ālāt al-sāʿāt allatī tusammā rukhāmāt* 158, 160, 489
*Fī ʿamal shakl mujassam dhī arbaʿa ʿashara qāʿida* 455
*Fī annahu idhā waqaʿa khaṭṭ mustaqīm ʿalā khaṭṭayn mustaqīmayn* 465
*Fī anna al-khaṭṭayn idhā ukhrija ilā al-zāwiyatayn aqall min al-qāʾimatayn itaqayā* 465
*Fī al-ḥujja al-mansūba ilā Suqrāt* 455
*Fī misāḥat al-ashkāl al-musaṭṭaḥa wa-l-mujassama* 451
*Fī misāḥat al-mujassamāt al-mukāfiya* 452, 627
*Fī misāḥat qaṭʿ al-khuṭūṭ* 451
*Fī quṭūʿ al-usṭuwāna wa basīṭihā* 473
*Fī shakl al-qaṭṭāʿ* 483
*Kitāb al-qarasṭūn* 617–18, 620, 622, 626–8
*On the deceleration and acceleration...* 56, 418
*On the Sections of a Cylinder and its Surfaces* 421, 425, 451
*On the Volume of the Paraboloid of Revolution* 421
*Tashīl al-Majisṭī* 292
*The visibility of the crescent by calculation* 41
*The visibility of the crescent by tables* 41
(attributed to Thābit in the Middle Ages)
*De anno solis* (*On the solar year*) 26–31, 289; *Liber de motu octavae spherae* 259–60, 289–90, 296, 298, 300, 303
Theodosius
*On Days and Nights* 7, 18
*On Habitations* 7, 18
*Spherics* 7, 18, 448
Theon of Alexandria
*Commentary on the Almagest* 525
*Commentary on the Handy Tables* 7
Theophilus
*Diversarum artium schedula* 886–7
Theophrastos
*Causes of the Plants* 813, 817
Tideus
*De aspectibus* 718
Ṭughrāʾī
*Ḥaqāʾiq* 860
*Kitāb al-maṣābīḥ wa-l-mafātīḥ* 873
*Lāmiyyat al-ʿajam* 873
*Mafātīḥ al-raḥma wa maṣābīḥ al-ḥikma* 873
al-Ṭūsī, Naṣīr al-Dīn
*Jawāmiʿ al-ḥisāb* 338
*Kashf al-qināʿ ʿan asrār al-shakl al-qaṭṭāʿ* 483, 515–19, 532
*Risāla al-shāfiya ʿan shakk fī al-khuṭūṭ al-mutawāziyya* 468–9
*Tadhkira fī ʿilm al-hayʾa* 93–4, 97, 117, 127
*Taḥrīr al-Majisṭī* 94
*Taḥrīr Uqlīdis* 462, 468–9
al-Ṭūsī, Sharaf al-Dīn
*On the Equations* 362–70, 373–5

al-Umawī
*Marāsim* 341–2
al-Uqlīdisī
*The Arithmetic* 332
*al-Fuṣūl fī al-ḥisāb al-hindī* 331, 335, 336, 338, 340, 383, 548
al-ʿUrḍī
*Kitāb al-hayʾa* 93, 97, 106–8
Urso
*Anatomy* 969
*De commixtionibus* 968
*De effectibus qualitatum* 968
*De gradibus* 968

Vincent of Beauvais
*Speculum doctrinale* 873
*Speculum naturale* 873
Vindanios Anatolios
*Synagoge* 816

Wallis, J.
*De Postulato Quinto et Definitione Quinta lib. 6 Euclidis* 469
William of Conches
*Philosophia mundi* 965
William of Saint-Cloud
*Almanach* 296
William of Saint-Thierry
*De natura corporis et anime* 966
Witelo
*Perspectiva* 493, 555, 721, 728

Yaʿqūb b. Ṭāriq
*Kitāb al-ʿilal* 20
*Tarkīb al-aflāk* 20
*Zīj maḥlūl fī al-Sindhind li-daraja daraja* 20

al-Zahrāwī
*Taṣrīf* 252, 818, 920–1, 947, 970, 983
Zenodorus
*On the Isoperimetric Figures* 437–8
Zetzner
*Theatrum chemicum* 875
Zosimus
*Kitāb al-ʿanāṣīr* 857
*Kitāb ilā jāmiʿ al-ḥukamāʾ* 857
*Kitāb al-mafātīḥ fī al-ṣanʿa* 857
*Kitāb al-sabʿūna risāla* 857
*Muṣḥaf al-ṣuwar* 857